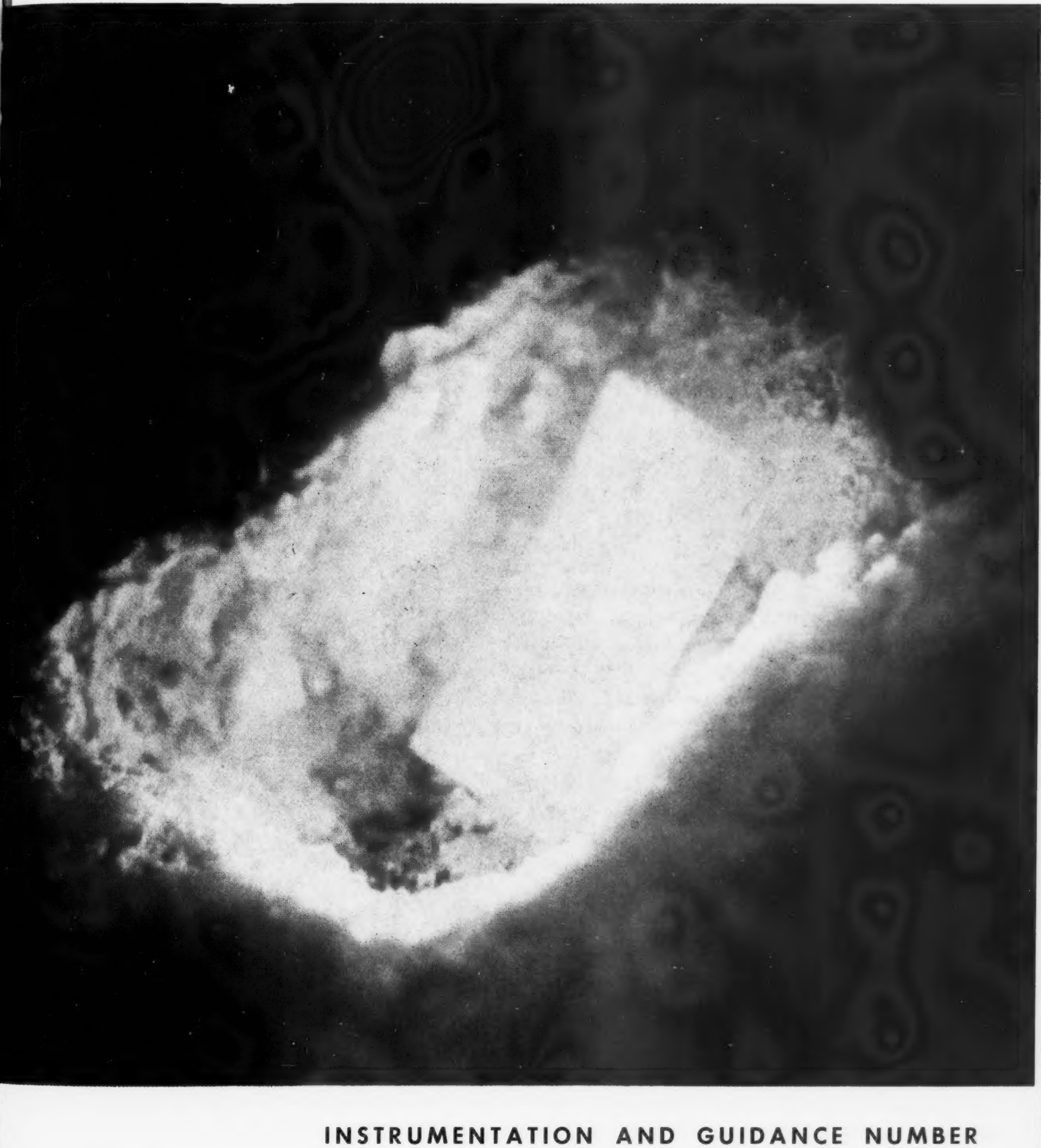
Astronautics

A PUBLICATION OF THE AMERICAN ROCKET SOCIETY

MAY 1958



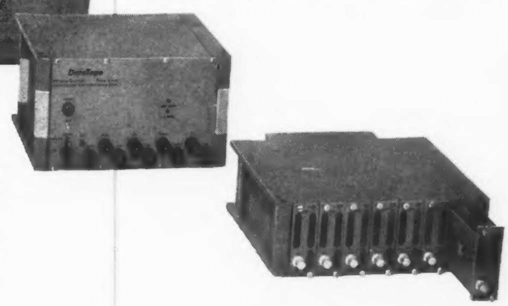
INSTRUMENTATION AND GUIDANCE NUMBER

announcing CEC's new

airborne **DataTape** *system*

DATATAPE RECORDER

CEC's *all new Type 5-702* provides up to 14 tape tracks, instant selection of tape speed, with large capacity of ½″ or 1″ tape on 10½″ reels. The mounting of reproduce headstacks permits downstream monitoring of all tracks coincident with the collection of data, also converts the Recorder to a ground laboratory playback machine.



NEW MINIATURIZED ELECTRONICS

Record Amplifiers—Seven record amplifier plug-in modules can be housed in a single amplifier case—the smallest package on the market today. 10-20 oz. modules (6¼″ long by 3¼″ high and 1-3/16″ wide) provide FM, PDM, or Analog recording. No shockmount is required. Write for following bulletins:
Analog, Bulletin CEC 1592-X3.
PDM, Bulletin CEC 1594-X3.
FM, Bulletin CEC 1595-X3.

Power Supply weighs only 17 pounds. Only one unit is required to supply any combination of 14 record amplifiers. No shockmount is required.

5-752 Recorder/ Reproducer

Continuous Loop Transport

Now, for the first time, you can get precise magnetic tape data at extreme altitudes and temperatures to 100°C—performance guaranteed by the most compact airborne system available today. DataTape's unique combination of advantages include outstanding miniaturization, all metal-surface magnetic heads, and rugged, modular construction. No shockmounts are required. The new airborne system is completely compatible with CEC's 5-752 Recorder/Reproducer. *Contact your nearby CEC field office for complete information, or write for Bulletin CEC 1607-X3.*

Compare these features:

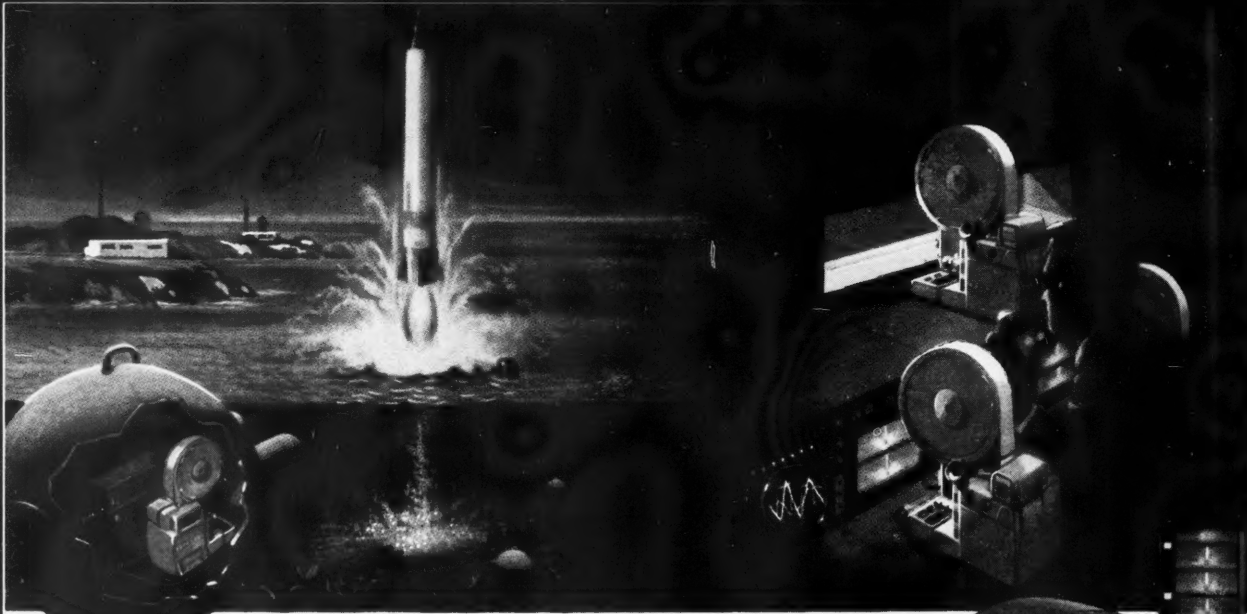
- ALL-METAL-SURFACE MAGNETIC HEADS
- DESIGNED FOR HIGH-TEMPERATURE OPERATION
- CAST ALUMINUM ALLOY CONSTRUCTION
- MINIATURIZED—MODULAR DESIGN
- SIX TAPE SPEEDS . . . ELECTRICALLY SELECTED WITHOUT BELT CHANGES

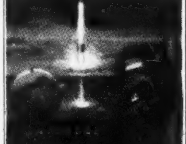
DataTape Division

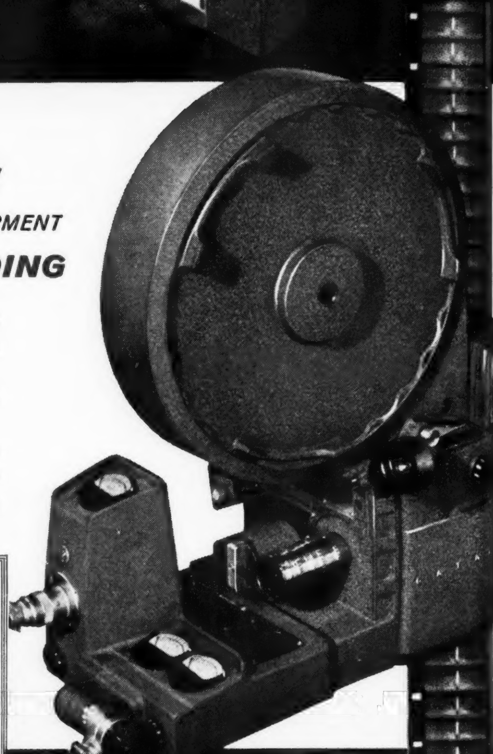
Consolidated Electrodynamics CEC

300 No. Sierra Madre Villa, Pasadena, California

OFFICES IN PRINCIPAL CITIES THROUGHOUT THE WORLD







A 10-CHANNEL HIGH-FIDELITY MAGNETIC-TAPE RECORDER WHICH ALSO TAKES DATA-MOTION-PICTURES!

Astronautics

A PUBLICATION OF THE AMERICAN ROCKET SOCIETY, INC.

May 1958 volume 3 number 5

INSTRUMENTATION AND GUIDANCE NUMBER

EDITORIAL

FEATURES

DEPARTMENTS

ASTRONAUTICS is published monthly by the American Rocket Society, Inc., and the American Interplanetary Society at 20th & Northampton Sts., Easton, Pa., U.S.A. Editorial offices: 500 Fifth Ave., New York 36, N. Y. Price: $9.00 a year; $9.50 for foreign subscriptions; single copies $1.50. Second-class mail privileges authorized at Easton, Penna. Notice of change of address should be sent to Secretary, ARS, at least 30 days prior to publication. Opinions expressed herein are the authors' and do not necessarily reflect those of the Editors or of the Society.

astro notes

R&D

• One problem coming in for a good deal of study these days is booster recovery, especially in space vehicles, where anything that can cut costs is welcome. There are a lot of elements in the problem, but two different systems are being considered. One would employ parachutes, an effort being made to recover the booster stage from the water. The other would call for jet engines, and possibly a ducted fan propulsion system, with a pilot flying the vehicle back.

• Marquardt's Astro Div. is pushing research work on very high supersonic ramjets, has completed facilities for testing engines at simulated runs up to Mach 12. Good progress is also reported on the Project Pluto nuclear ramjet engine.

• Despite all the publicity, flight testing of the final version of the X-15 is not likely to get under way before the middle of next year. Flight testing of the airframe and other components is set to begin late this summer, but RMI's engine is not slated to be installed in the ship before 1959.

• A manned ballistic rocket system is currently under study by a team made up of McDonnell Aircraft, Convair, North American and Avco.

• Ryan Aeronautical recently proposed "slingshot" launching of a manned hypersonic glider. A rocket sled platform providing acceleration to about 500 mph would be used to bring the vehicle to airborne speed. At this point, the pilot would cut in the glider's own liquid-fuel rockets, cut the vehicle loose from the sled, and fly the vehicle into a ballistic trajectory.

SPACE FLIGHT

• With NACA now regarded as the best bet to take over the national space flight program, other government agencies with an interest in astronautical projects are working closely with NACA in planning for the future. ARPA and NACA see eye to eye in many areas and ARPA has been consulting with NACA in regard to future projects, such as the lunar probes. Other civilian agencies mentioned as possibilities to handle the national astronautical program, such as AEC and NSF, are now regarded as dark horses, although NSF will undoubtedly be given the role of handling research in support of the ARPA-NACA space flight effort.

• "Too little—and possibly too late." That's the reaction among many Pentagon officials to present plans for lunar probes. Both AF and Army are upset over the fact that they were not informed in advance as to which of their many space flight proposals were being given serious consideration. Also, initial $8 million outlay for the project is regarded as ridiculously low, AF brass noting that the rocket engine boosters alone for its vehicles would cost about $750,000 each.

• Astronautical symposiums are becoming so frequent as to keep engineers and scientists away from their desks a good portion of every month. On March 25–27, for example, there was the three-day symposium on High-Speed Aerodynamics and Structures at San Diego. At the end of April, there was the AFOSR Astronautical Symposium at Denver. For the future, there's a symposium on missiles and space flight, co-sponsored by Ramo-Wooldridge and AF Ballistic Missile Div., scheduled for Los Angeles in June, as well as a Lockheed-Navy session on satellites, now in the planning stages.

SATELLITES

• A 12-ft spherical balloon designed to measure air drag and provide data on density of the high atmosphere will be launched in a future Explorer firing. Made of plastic film covered by aluminum foil, the balloon would be visible to the naked eye at dawn and dusk at altitudes of 800 miles or even more. Launched in a polar orbit, it could be seen over much of the U. S. The balloon, along with the bottled gas needed to inflate it, would be carried to orbital altitude within the satellite proper. Sphere and gas will weigh about 15 lb. A similar experiment, using a much smaller balloon, is also planned for Vanguard firing.

EDUCATION

• ARS West Coast Student Conference, to be held in conjunction with the Semi-Annual Meeting in Los Angeles June 9–12, is shaping up as an outstanding event. Andrew Charwat of UCLA, Conference Chairman, is rounding up a top-notch panel to discuss areas where students can make major contributions to the state of the art.

• AF Academy has created a Department of Astronautics, to be headed by Col. Benjamin P. Blasingame, who will report to the Academy this month after completing a three-year tour of duty with the AF Ballistic Missile Div. The new department will teach the physics of manned and unmanned space flight, with first-class cadets (seniors) beginning to take major elements of the course this Fall.

MISSILES

• With Fairchild's fiberglass-bodied Bull Goose already fired successfully, test firings of other missiles of the plastic decoy variety, designed to confuse enemy radar defenses, will be coming up in the near future. In this category are Fairchild's Gander, similar to the Bull Goose, but armed with a nuclear warhead, and McDonnell's Green Quail.

• Ground tests of the AF Titan ICBM were completed in March, and flight testing of the Martin Co. vehicle is scheduled to begin within a few months.

DRONES

• Interest in rocket-powered drones for surveillance and target use is growing apace. RMI recently announced completion of development of an off-the-shelf engine which can be tailored to meet all military drone requirements. Meanwhile, miniaturization and growing use of transistors are solving most of the electronic problems. Texas Instruments, for example, can now outfit drones with transistorized magnetic detection, IR detection and reconnaissance radar.

ELECTRONICS

• Leading topic of conversation at the recent IRE meeting in New York City was the transistor, rapidly replacing the vacuum tube in many missile applications. Electronic engineers agree vacuum tube is still important in high-power servo applications, but see transistors taking over more tube functions as semiconductor R&D work finds the answers to present problems. One important advantage of the vacuum tube: Price. Transistors still cost more than tubes.

• Heard at the IRE Show: "These gadgets are getting so small we're having trouble finding a place to put the names on 'em!"

ABROAD

• Soviet Boss Nikita Khruschev has changed his mind about the relative roles of missiles and manned aircraft, now feels the importance of conventional aircraft is declining only "somewhat" as missiles come into operative use. This contrasts with his statements last year about "obsolescence" of manned bombers.

• The Italian Center for Research on Jet Propulsion, co-sponsored by industry and the government, is swinging into high gear. Main interest: Systems organization.

ROUNDUP

• GE is thinking of getting into the solid propellant business. First item on the agenda: Construction of a $200,000 pilot plant in Cincinnati, expected to be in operation early this fall if present plans materialize.

• IGY rocket teams at Fort Churchill are justifiably proud of the firing record they have compiled. They're now working on a string of 20 successful firings (Aerobees, Aerobee-Hi's and Nike-Cajuns) in a row.

• Appointment of Wallace R. Brode, AAAS president, as science adviser to State Department, has won plaudits of scientists. Dr. Brode, heading up program designed to keep watchful eye on scientific developments overseas, is seeking top men to act as scientific attachés at U. S. embassies abroad.

capital wire

News highlights from Washington

SPACE FLIGHT

• Announcement by White House that U.S. will launch lunar probes indicates plans for a national astronautical program are shaping up. ARPA will direct the project, for which $8 million has been allocated initially. AF will launch three vehicles, Army one or two under the program. AF has assigned job to its Ballistic Missiles Div., will use three-stage vehicle with Thor IRBM as first stage, second stage borrowed from Vanguard and third stage yet to be developed. Army firings will be handled by ABMA, utilizing modified Jupiter-C's. Primitive TV equipment may be carried by some vehicles. No timetable has been set.

• "Space Primer" compiled by the President's Science Advisory Committee follows pretty well national astronautical programs previously presented to the government by ARS, the Rocket and Satellite Research Panel (now affiliated with NAS), NACA and the IGY Satellite Panel. One thing was added—an estimate of what a manned flight to the moon would cost. The guess: $2 billion. The report was also on the pessimistic side, indicating such a voyage might not be feasible until the next century.

• NACA Space Flight Committee Working Groups have been quite active, perhaps in anticipation of assignment of national space flight program to the agency. Objectives group, under James A. Van Allen, has been mapping an astronautical timetable and deciding on specific missions and projects. Vehicular programs group, under Wernher von Braun, is determining what type of vehicles could and should be built with existing resources and what will be needed for future missions.

• Appointment of Herbert F. York, former director of the UCal Livermore Laboratory, to be Chief Scientist of the Advanced Research Projects Agency, has been hailed by missile men. A top nuclear physicist, Dr. York also is a long-time member of the Army Ballistic Missiles Advisory Committee. Appointment of several nuclear propulsion experts to top ARPA posts is taken as indication of the agency's thinking.

SATELLITES

• Explorer and Vanguard data are being carefully studied for clues as to what the X-15 will face when first test flights are undertaken later this year. Initial data indicate meteorite density is not as great as was previously expected, that cosmic ray bombardments will probably not be dangerous except on very long flights and that temperatures encountered will not extend too far beyond ranges found on earth.

• Army, with two successful satellite firings already under its belt, has been given go-ahead signal on two or three more. While the Explorer III firing was not entirely successful from the technical standpoint, with high-speed stages of the Jupiter-C failing to fire at the proper time, the unusual orbit into which the satellite fell meant that valuable new data were accumulated. First data indicated cosmic rays and temperatures were falling within expected limits.

MISSILES

• Assignment of Pershing solid propellant medium-range ballistic missile to The Martin Co. is regarded as first step away from Army arsenal concept, defended as recently as last summer by Army Secretary Wilber Brucker. While development program will be "under control" of ABMA, Martin will be responsible for R&D work, testing and production not only of the missile itself, but also of associated ground equipment. Initial contract is reportedly $20 million.

• AF design competition for Minuteman solid propellant multipurpose ballistic missile project (April ASTRONAUTICS, page 5) will be held during next six months. Contractor for Minuteman all-inertial guidance system will also be selected by this fall. Thiokol, Aerojet and Astrodyne are developing engines, while Convair, Douglas, Lockheed, Martin, North American and Ramo-Wooldridge are reportedly seeking the airframe contract.

ANTI-MISSILE MISSILES

• The Johns Hopkins Applied Research Laboratory has proposed a Mach 5–10 Talos for possible use as an anti-missile missile. An advanced twin ram-jet engine could boost the Navy surface-to-air missile from its present Mach 2 capability to Mach 10 and extend its range from 70 to over 100 miles, the proposal states. Hitch: It might take as long as 10 years to do the job.

• AF-Army battle over anti-missile missiles continues, with new argument raging over who will operate Nike-Zeus. Army claims recent decision by Defense Secretary McElroy calling for Army development of the missile implies operation as well; AF says this isn't so.

RESEARCH AND DEVELOPMENT

• Bell's Dyna-Soar Project, a feasibility study for a rocket-boosted manned hypersonic glider initiated seven years ago and carried out under an AF contract for the past three years, is approaching the hardware stage. One problem: A rocket engine with thrust considerably greater than that available from any of our present engines is required.

• Aerojet, in cooperation with the Post Office Dept., is studying construction of a transcontinental tube to be used for carrying rocket mail across the country at supersonic speeds.

• Aero Medical Assn. at meeting here revealed work now being carried out to devise a "space diet." Best bet at the moment: A synthetic food resembling sugar water thickened with shreds of paper towel and made by reprocessing human waste products.

for the record

The month's news in review

Mar. 1—AF sees perfected Thor combat-ready by June.

Mar. 3—AF gets Defense Dept. go-ahead to develop Minuteman solid fuel ICBM, is told to consider using Navy's Polaris for the project.

—Administration rejects AF proposal to speed development of first atomic-powered plane.

Mar. 5—Explorer II fired by Army (is unsuccessful).

Mar. 6—Army says Explorer II failed to orbit, probably burned up on re-entering atmosphere.

—President Eisenhower bars hurried building of atomic plane for prestige purposes.

Mar. 7—Analysis of Explorer I data indicates marked increase in intensity of cosmic rays outside earth's atmosphere.

—Navy commissions Grayback, first sub equipped to fire Regulus II missiles.

Mar. 12—Five AF officers enter mock-up B-36 at Wright-Patterson AFB for five-day simulated trip into outer space.

Mar. 13—Lt. Gen. Donald L. Putt, AF R&D chief, retires, reportedly because of differences with DOD policy on outer space development.

Mar. 15—Maj. Gen. John B. Medaris, Army missile chief, asserts only military is equipped to explore outer space.

—AF discloses Titan will be ready for flight tests this year.

Mar. 16—Army reports use of metallic "confetti" in Loki rockets to plot high-altitude winds.

Mar. 17—Navy puts 6.4-in. Vanguard satellite into orbit.

—Gen. Thomas D. White, AF chief of staff, urges over-all civilian control of outer space exploration.

Mar. 18—Navy fires Bull Goose "decoy" missile.

—Herbert F. York is named chief scientist of ARPA.

—Secy. Dulles rejects Soviet proposal for outer space control.

Mar. 19—U.S. IGY Earth Satellite Panel drafts long-range space research program.

Mar. 20—Maj. Gen. John B. Medaris is named head of new Army Ordnance Missile Command, putting ABMA, Jet Propulsion Lab, Redstone Arsenal and White Sands Proving Ground under single command.

Mar. 24—Defense Dept. authorizes Navy to ask funds for quick start on two more subs designed to fire Polaris missile.

Mar. 25—Army, departing from basic policy, assigns development, testing and production of solid-fuel Pershing missile to The Martin Co.

Mar. 26—Aero Medical Assn. scientists say man could safely make four-day trip to moon and back with existing equipment.

Mar. 27—U.S. plans to probe space around moon, allots $8 million initial outlay.

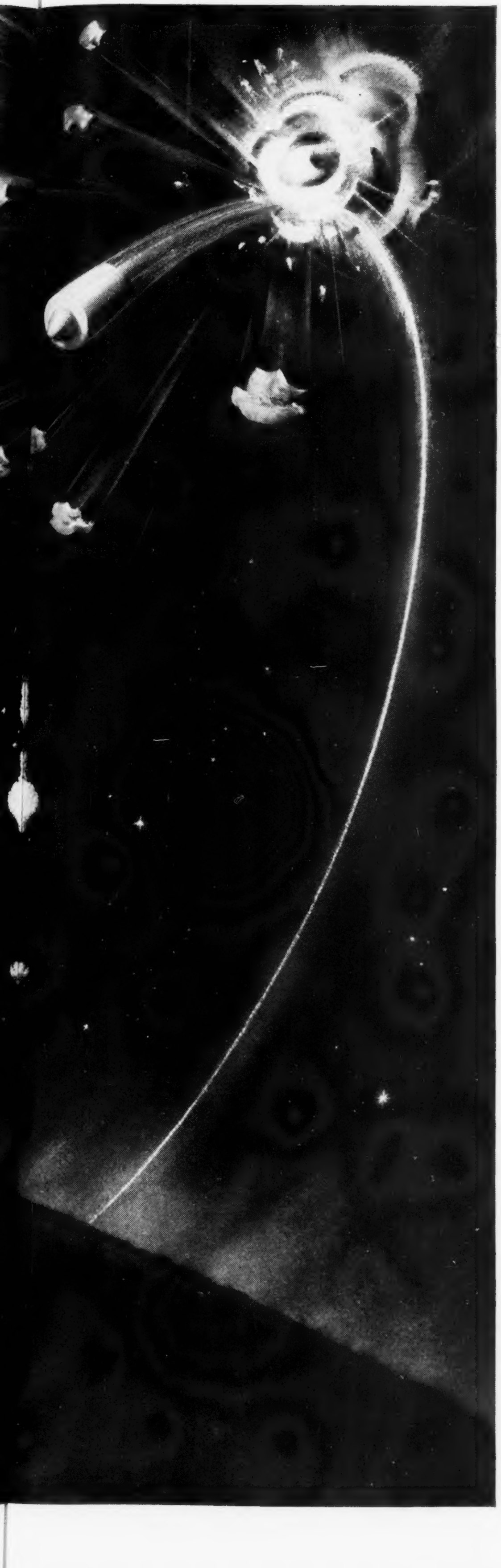
Mar. 29—Army announces plans to fire 12-ft inflatable balloon from future Explorer.

—USAF Academy creates Dept. of Astronautics.

—Navy announces plans to place yeast packet in future Vanguard to test reaction of living organism in absence of gravity.

Mar. 30—U.S. Office of Education issues set of instructions and safety measures for young rocketeers.


LACROSSE
Swift and deadly, the Martin Lacrosse is the Army's newest artillery weapon. The rocket-propelled Lacrosse provides pin-point precision with tremendous destructive power against enemy targets.
The rugged simplicity of its powerful THIOKOL solid propellant engine gives the truck-mounted missile extreme mobility in the field.
With the Lacrosse, Army ground troops have guided missile support where they need it — when they need it.
U.S. ARMY
Thiokol®
CHEMICAL CORPORATION
TRENTON, N. J. • ELKTON, MD.
HUNTSVILLE, ALA. • MARSHALL, TEXAS
MOSS POINT, MISS. • BRIGHAM CITY, UTAH
® Registered trademark of the Thiokol Chemical Corporation for its liquid polymers, rocket propellants, plasticizers and other chemical products.



HOW CAN AN ANTI-MISSILE MISSILE TELL A DECOY FROM THE REAL McCOY?

TO CONFUSE anti-missile missiles, an incoming missile may explode its final stage rocket casing as it approaches target. The resulting fragments would surround and travel with the missile, acting as decoys.

This is only *one* of the AMM guidance and arming-fuzing problems.

There is also the fantastic closing speed of the two missiles which allows only seconds to resolve and relay course correction data to the launched AMM. And there are environmental problems of extreme acceleration, vibration, velocity and heat that exceed even those found with ICBMs.

At Honeywell, however, solutions are in sight.

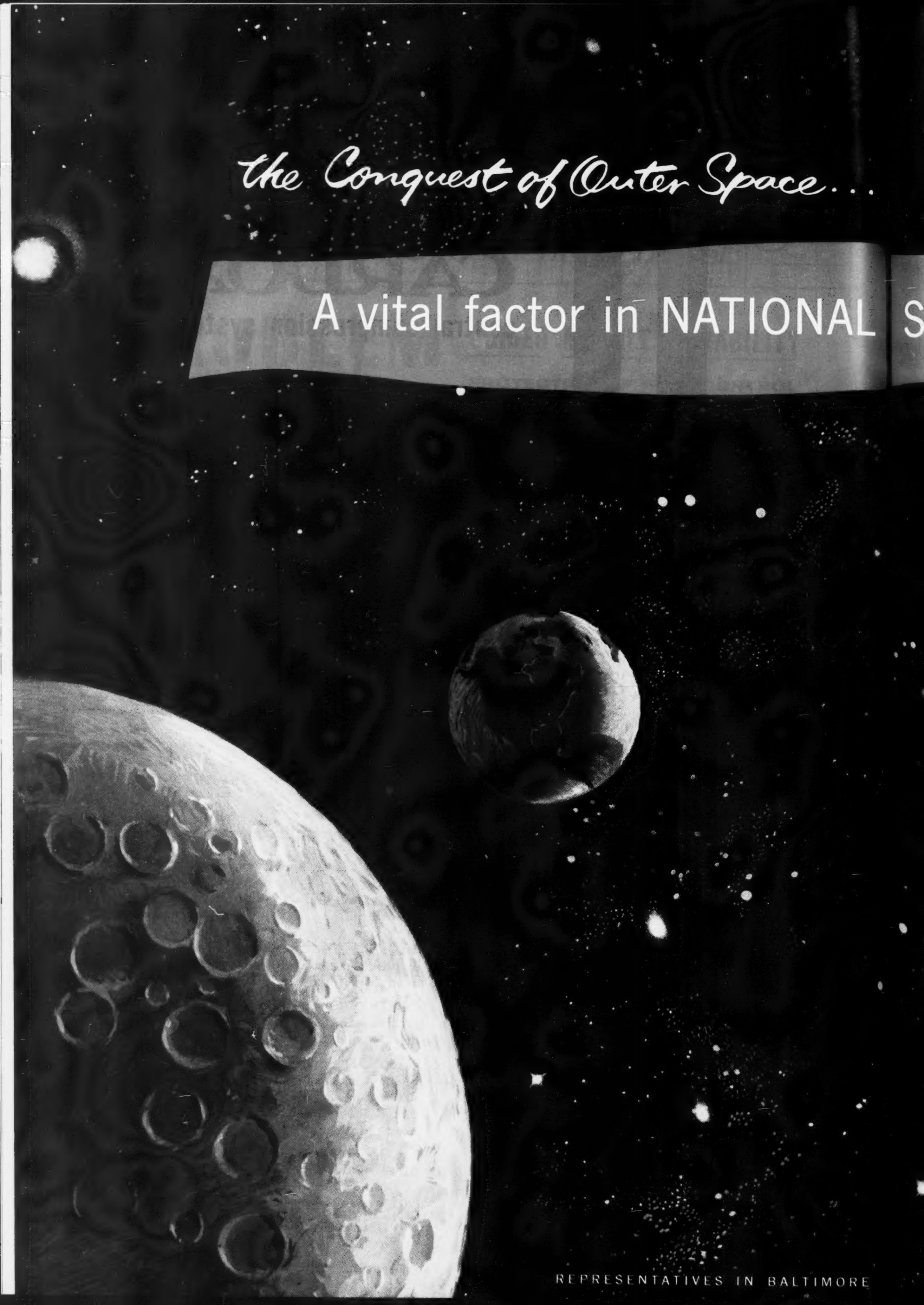
The decoy problem may be solved by detecting a piece of the enemy missile near the center of the fragment cloud and ignoring individual pieces. Or, if the fragment cloud does not exceed the effective explosive radius of the AMM warhead, the AMM fuse can simply act on the entire cloud.

For further information, contact Minneapolis-Honeywell, Military Products Group, 2753 Fourth Avenue, South, Minneapolis 8, Minnesota.

The fuzing system for Sidewinder is now being manufactured by Honeywell in quantity. And Honeywell is also producing systems, sub-systems and components for ASROC, Wagtail, Thor, Titan and many classified missiles. This broad systems experience makes Honeywell the logical company for anti-missile missile development work.

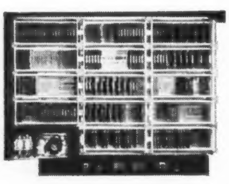
Honeywell

Military Products Group



the Conquest of Outer Space...
A vital factor in NATIONAL S
REPRESENTATIVES IN BALTIMORE

The RW-300 is the first digital computer for test control and data reduction



Now—at the test site—completely automatic test control and data reduction can be handled by a single system incorporating the Ramo-Wooldridge RW-300 Digital Control Computer. The new RW-300 can schedule and closely control test routines, and it can collect, analyze, and record test data.

The versatile RW-300 utilizes input data as feedback to modify control actions, thus substantially shortening many test routines. In addition, the RW-300 directly logs both instrument data and complex relationships among these data. Thus, test results are available immediately. The time-consuming task of processing raw data through a separate computer, often remote from the test facility, usually can be eliminated.

For technical information on automatic test control and data reduction with the RW-300 and with special digital systems which utilize solid-state components exclusively, write: Director of Marketing, The Thompson-Ramo-Wooldridge Products Company, P.O. Box 45607, Airport Station, Los Angeles 45, California, or call OSborne 5-4601.

THE THOMPSON-RAMO-WOOLDRIDGE PRODUCTS COMPANY

COVER: *Raytheon graphitic material sits tight at surface temperature of 3800 F under oxidizing flame as firebrick melts. New missiles and atomic-powered space ships will carry electronic materials to this high-temperature frontier* (*see page 25*).

Astronautics

MAY 1958

From the Editor's Desk

This issue of ASTRONAUTICS was actually born almost a year ago, when Dr. Simon Ramo of Ramo-Wooldridge Corp. suggested it might be a good idea if the new AMERICAN ROCKET SOCIETY publication took a long, hard look at the missile electronics field some time in the not-too-distant future.

Dr. Ramo, now Chairman of the ARS Publications Committee, graciously consented to work closely with the editors in selecting general areas to be covered in the issue and even in suggesting possible authors for the articles.

The result is what we feel to be the most comprehensive picture presented to date of the state of the art of astronautical instrumentation and guidance. In this instance, the word "astronautical" is used advisedly, since almost every author represented in this issue, while asked to examine only the present state of the art, has also looked into the future to examine requirements in terms of tomorrow's space vehicles.

While it would be foolhardy to claim that this entire field could be fully covered in one issue of any publication—even a dozen issues would scarcely suffice—the baker's dozen of articles presented here offers an indication of what has been accomplished to date, and what still remains to be done, in guidance, instrumentation, telemetry, data handling and processing, materials development, etc.

Even more important, this issue provides graphic proof, if such proof were still needed, of the fact that astronautics today embraces a vast number of varied sciences and technologies, each playing a major role in the development not only of present-day weapon systems, but also of the vehicles which will carry man to the stars.

Irwin Hersey
Editor of ASTRONAUTICS

Electronics and the missile

Development of components specifically for missile applications, size and weight reduction, and important discoveries have marked the first ten years of a new industry, but a good deal still remains to be done

By Jerome B. Wiesner

RESEARCH LABORATORY OF ELECTRONICS,
MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MASS.

Jerome B. Wiesner is professor of communication engineering at the Massachusetts Institute of Technology, director of MIT's Research Laboratory of Electronics and a member of the staff of Lincoln Laboratory. A graduate of the University of Michigan, where he received his Ph.D. in 1950, Dr. Wiesner was formerly chief engineer of the Library of Congress and staff member of the MIT Radiation Laboratory and the University of California Los Alamos Laboratory. A fellow of the Institute of Radio Engineers and of the American Academy of Arts and Science, he is a consultant to the Department of Defense and a member of the Scientific Advisory Committee to the Secretary of Defense, the Army Scientific Advisory Panel and the President's Science Advisory Committee.

THIS REVIEW of the state of the electronics art associated with the design and construction of missiles is particularly timely. The nation is just now awakening to the need for a greatly intensified effort in the missile, anti-missile and air defense fields. What's more, the world is poised for scientific flights into space, and the guidance, control and communication tasks inherent in these problems are considerably more difficult than any we have yet overcome.

Electronic devices constitute a large part of any guided missile system. Expenditures for the electronic elements, including ground environment equipment, ordinarily constitute more than half of the total cost of a missile. Because of the critical importance of the electronic elements and their difficulty of design and construction, the electronic system often plays an overwhelming role in determining the final characteristics and performance of the over-all missile system.

As a consequence, airframe manufacturers have had to establish large and technically competent electronic divisions in order to cope with missile problems. Firms whose primary competence was originally in the field of electronics have become prime contractors for missile system development. To do this, they have either found it necessary to associate with an aircraft company or build up their own aeronautical competence. Notable examples of this trend are the Bell Telephone Laboratories, which developed the Nike series of missiles for the Army, and Raytheon Mfg. Co., which has the primary responsibility for the Hawk missile.

Electronic devices have a number of separate functions in guided missile systems. They provide the "eyes" of a missile—that is, they provide the basic intelligence to direct the missile. They do the "thinking" for the missile—that is, compute the course the missile should follow to carry out its mission successfully. They also provide the control signals which actuate the missile control surfaces and control the operation of the motors.

In addition, electronic equipment is used in many auxiliary ways to provide communications with the missile when it is required, either in the form of data telemetered from the missile during its

Typifying the dramatic shrinking of size and weight of missile equipment in the past decade, six tiny Raytheon diffused-junction silicon rectifiers, weighing less than a pound with the frame, replace suitcase-size, 30-lb selenium rectifier.

development flights, or in the form of control signals if the missile happens to require information in flight from a remote point, as is often the case.

With such a heavy dependence placed upon electronic components, it is not surprising that the reliability (or often the unreliability) of a missile system is determined to a large extent by the performance of its various electronic subsystems.

In addition to influencing the reliability of the device, the properties of the electronic components also play a decisive role in determining the size and performance of a given missile system. Warhead yield and weight requirements are ordinarily controlled by the missile's miss distance. This, in turn, is controlled by the radar or infrared guidance system performance, gyro accuracy and control system performance.

Subsystem Compatibility Essential

Each subsystem of a guided missile must be compatible with the other subsystems if satisfactory performance is to be obtained, and consequently it is important that the specification of the properties of the electronic components be under the control of the system designer. The overriding importance of such careful integration of the various subsystems into the missile was not clearly understood when guided missile development began shortly after World War II, and as a consequence it often took an inordinately long time to go from the appearance of the first experimental model of a given missile to the time when a satisfactorily operating system existed. In fact, the development period of many of the early missiles was so much longer than had been predicted by their enthusiastic sponsors that many people even today refuse to believe that it is possible to plan and produce a missile on schedule.

We have learned that the successful development of a guided missile is a much bigger job than many people imagined. Because it is impossible to make on-the-spot obser- (CONTINUED ON PAGE 114)

Today's candidate to retire the vacuum tube—the transistor. Bell Labs showed this experimental model in 1948. Transistors only now begin to show the versatility and reliability necessary for the "super" systems of tomorrow.

Fundamentals of missile guidance

Accurate guidance is a must if a missile is to carry out its mission. . . Beam rider, command and homing systems, as well as Doppler radar, inertial and celestial navigation, are all being used to get the job done

By John R. Moore and Charles P. Greening

AUTONETICS, A DIVISION OF NORTH AMERICAN AVIATION, INC., DOWNEY, CALIF.

MISSILE GUIDANCE means the directing, to an enemy target, of a vehicle containing explosive. To be practical, the missile must go very swiftly and the guidance system must operate accurately and without fail. Obviously, this combination of requirements brings up technical problems of remarkable difficulty.

While some overlap exists, guided missiles may be thought of as falling into one of two classes, depending on whether the target is moving or stationary.

For moving targets, the missile is relatively small. The short range requires less propulsion fuel, and, in some cases, the nature of the target demands less explosive for destruction. In any event, the missile has to be reasonably small for the sake of agility. For guidance, some sort of radiant energy contact is usually established with the target: Radar beam, detection of infrared from the target, etc. The missile is steered on a continuously computed course to intersect the target. The pursuer must always be more agile than the pursued, and accelerations of the order of 10–100 g may be encountered.

In this situation, the principal problems are those associated with the operation of electromechanical equipment in the rugged environment of a high-speed, violently maneuvering missile, and interpretation of target position information in a form intelligible to the missile autopilot.

Moore Greening

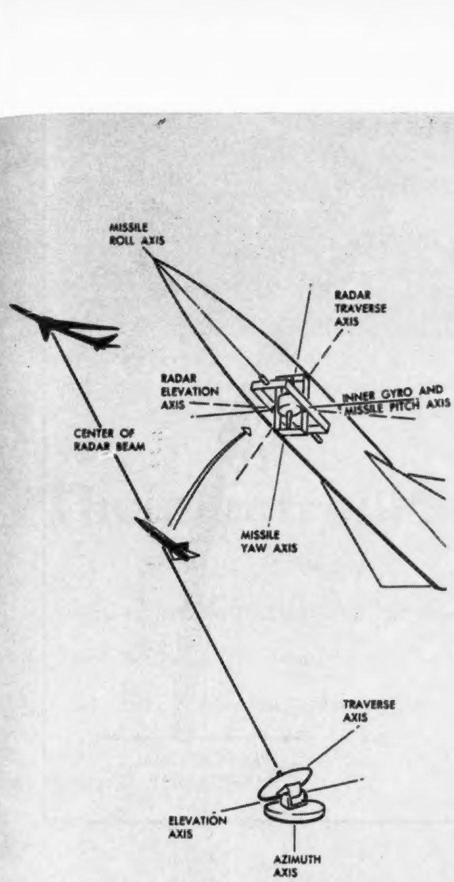
John R. Moore, vice-president of North American and general manager of its Autonetics Div., joined the company in 1948, becoming assistant director of the Electro-Mechanical Engineering Dept. in 1953 and director two years later. He was named head of the Autonetics Div. when it was formed late in 1955. A consultant on electronics for the Defense Department, he has authored a number of classified papers on missile guidance, ballistics, aircraft flight simulators and computers, and since 1949 has been a visiting associate professor of engineering at UCLA.

Charles P. Greening is on the staff of the Advanced Engineering Department of the Autonetics Div., specializing in inertial navigation. He came to North American in 1952 from the University of Washington, where he was an assistant professor.

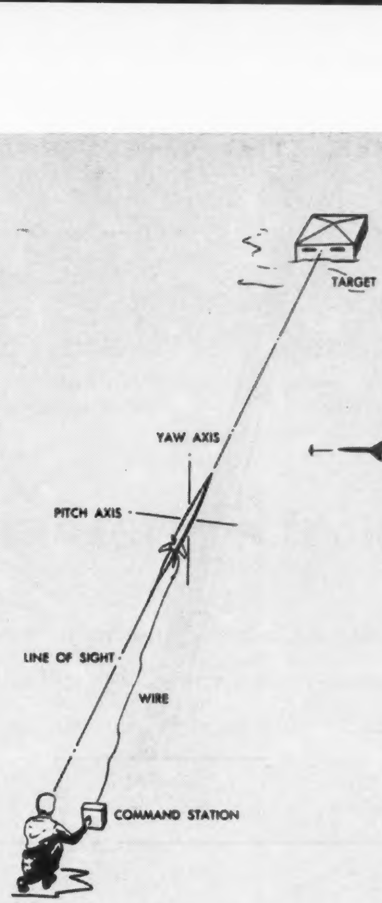
Mechanical Design Answers First Problem

The first of these problems is met by minute attention to the *mechanical* design of electronic and electrochemical equipment. The results tend to resemble only very remotely the kind of electronic equipment found in a home radio. The second problem, that of interpretation of error signals, also plays a major part in the entire guidance system design.

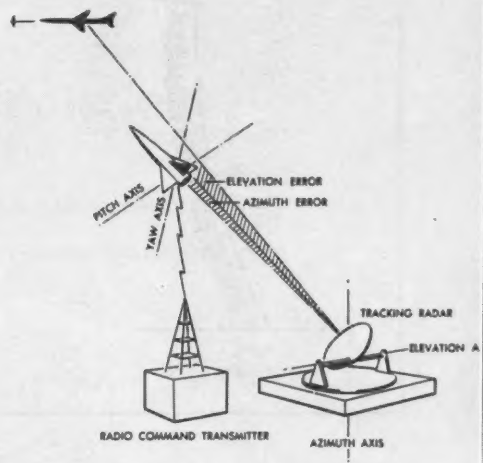
Consider the problems which arise in a beam rider guidance system for an antiaircraft missile, as shown on page 23. Here a ground radar tracks the target aircraft with a beam whose center axis establishes the line connecting the target and the radar. This is the target's instantaneous position vector relative to the ground. The missile flies "up the beam" until it hits the target.



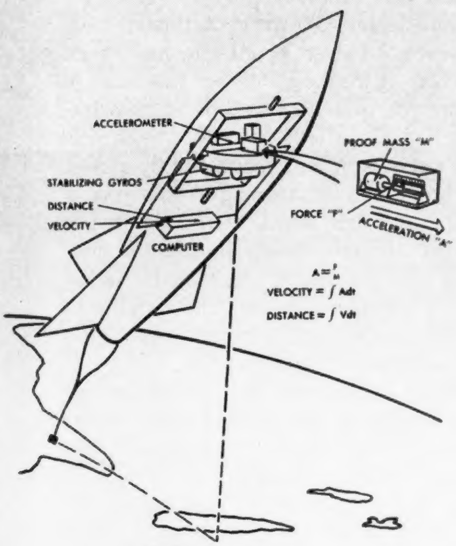
BEAM RIDER



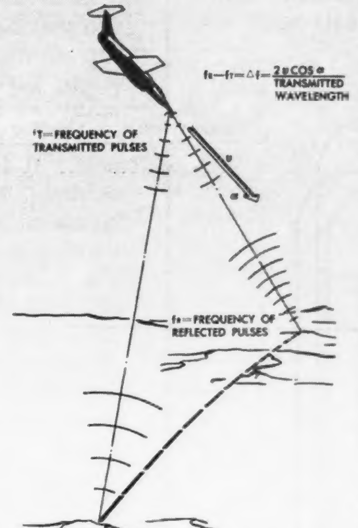
WIRE COMMAND



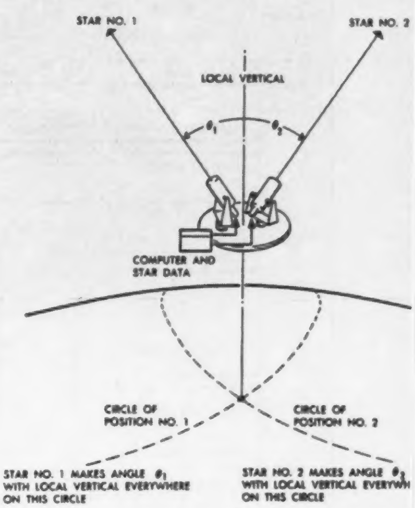
RADIO COMMAND



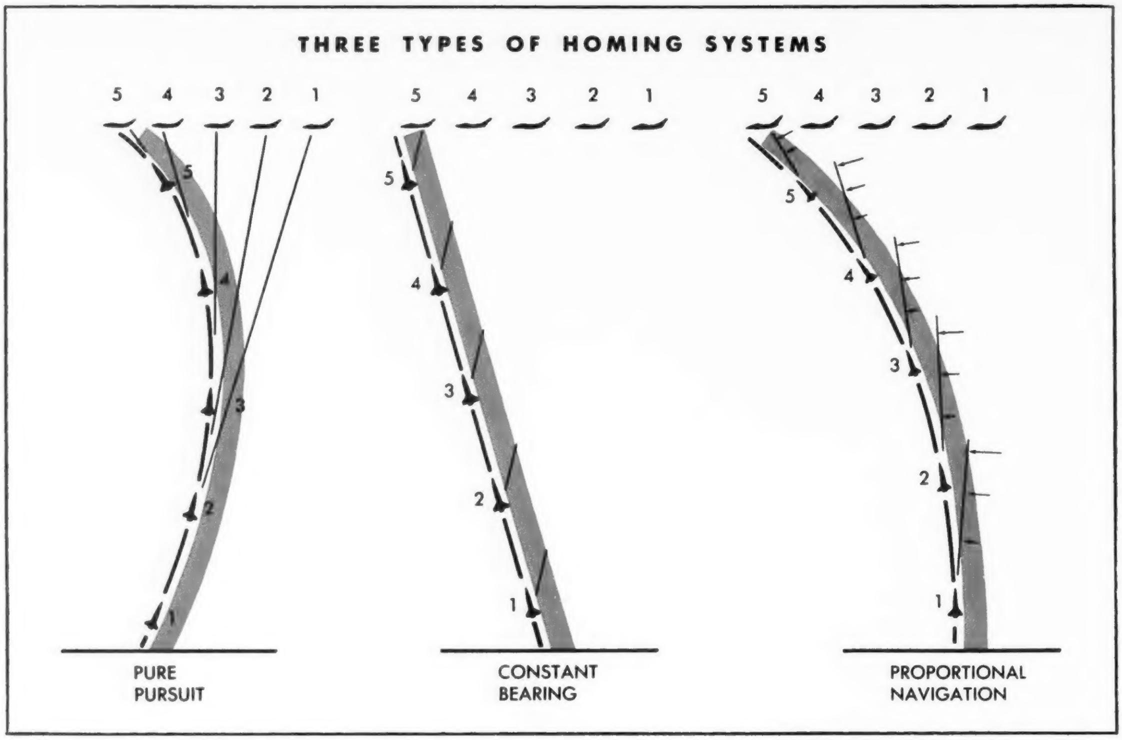
INERTIAL GUIDANCE

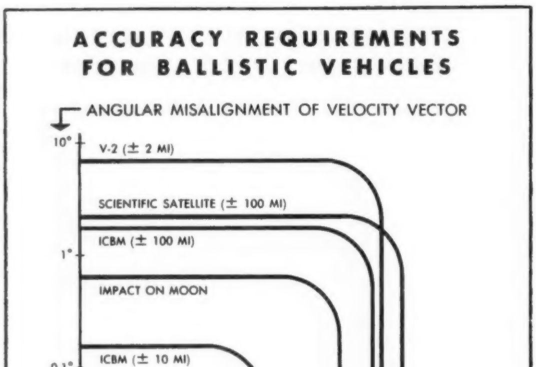


DOPPLER RADAR



CELESTIAL NAVIGATION

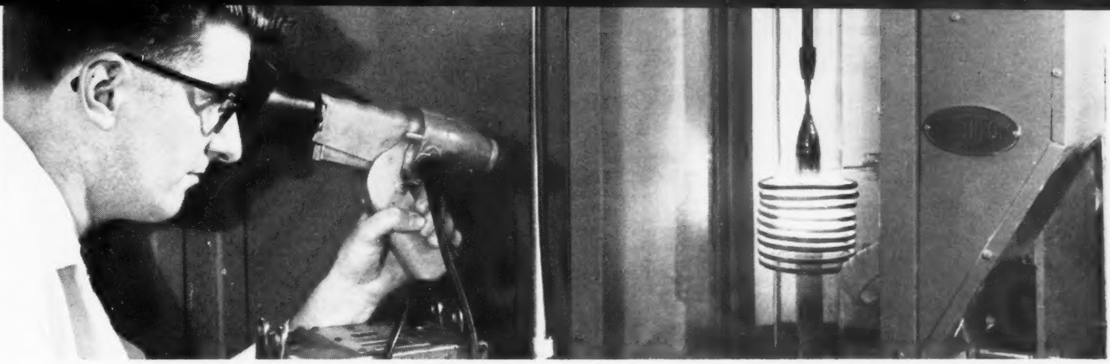




Although the basic concept seems simple enough, a closer analysis of the detailed problem reveals that some very difficult reference system relations exist.

First, the beam itself must be polarized in such a way that the missile, once off the central beam axis, can tell which way to steer in order to head back toward the center of the beam. Since the beam is controlled from the ground radar, beam polarization is established along axes associated with this radar. If the target is never expected to fly almost overhead, the radar can be mounted as shown on a horizontal, elevation axis which is rotated in the tracking process around a vertical azimuth axis. The polarization of the beam will then be established parallel to the elevation axis and parallel to the traverse axis (perpendicular to the plane of the elevation axis and the radar beam).

Missile guidance errors are thus established as displacements parallel to the ground radar elevation and traverse axes. These displacements are detected in the missile as identifiable radar signals. However, they are meaningful as steering signals only if the missile carries within itself some reference system which can be related to the radar axes. The complexities of this situation can be dramatized by considering the different missile orientations which must exist for two conditions—one, a target flying approximately along (CONTINUED ON PAGE 90)



Tiny "seed" crystal, lowered into crucible of molten silicon and slowly withdrawn, grows into huge single bullet-shaped pure silicon crystal. Technician checks temperature of molten metal with optical pyrometer.

The electronic materials frontier

While filling requirements for present-day weapon systems, electronic engineers are engaged in an all-out effort to determine the exact specifications for materials designed for use in tomorrow's space vehicles

By Harry Letaw Jr.

RESEARCH DIVISION, RAYTHEON MFG. CO., WALTHAM, MASS.

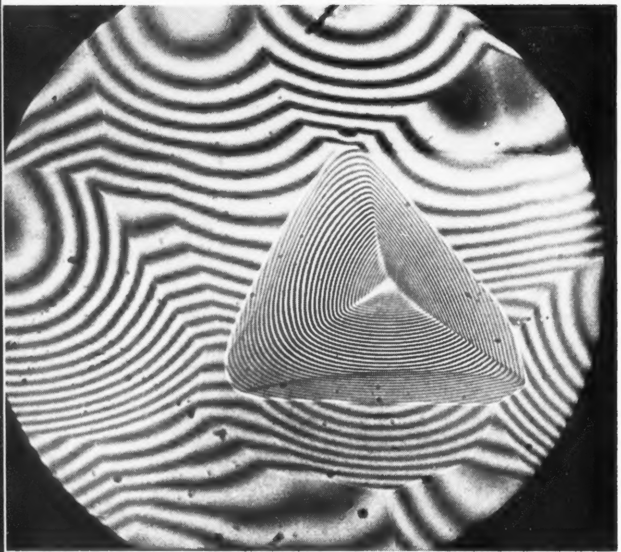
AS THE FRONTIERS of electronics advance into outer space, there is an ever-tightening requirement for systems that will operate in every conceivable environment. Performance specifications are hopefully generated in the classified and unclassified literature, in serious and fanciful proposals, and in design conferences across the nation.

The systems engineer quickly learns that off-the-shelf components for many of the required functions do not exist. The components engineer in turn faces the fact that seemingly realistic specifications are impossible of realization because materials with the given properties are not available. Finally, at the level of materials availability, many a major systems concept is grounded in its encounter with unrelenting reality.

Materials availability means that there exist proved production processes capable of producing an adequate supply of material *per se*, that the resultant product is sufficiently uniform for use, and that the product is of suitable quality and form. Finally, there must be sufficient knowledge of the product to be able to specify it for a given process.

Silicon carbide, for example, is available in ton lots at a relatively low price. Basic studies of silicon carbide have indicated that solid state devices fabricated from this material could operate at much higher temperatures than similar devices made from silicon. The semiconductor device engineer knows, however, that the silicon carbide of commerce is virtually useless for his purposes. Consequently, he can do no more than investigate the metallurgical process associated with the construction of silicon carbide transistors until the materials technologist provides a product of the desired

Harry Letaw Jr. is a staff member of Raytheon's Research Div. He is presently active in planning future military and scientific exploration systems requirements. Dr. Letaw, a graduate of the University of Florida, was research assistant professor of electrical engineering at the University of Illinois from 1952 to 1955, and during that time carried out basic research in diffusion and in the physics of semiconductors. At Raytheon, he has worked on semiconductor devices, and is now directing a program to develop infrared optical components.



Microinterferogram of surface etch pit in germanium illustrates an advanced research technique used in basic studies of semiconductor materials.

purity, atomic structure and form. Detailed electrical evaluation of the material must await the near-final product.

This does not imply, however, that materials availability alone controls progress in electronic components and systems. It is quite likely that materials already in adequate supply will permit design and fabrication of many of the electronic components of the future.

The generation of submillimeter waves, for example, may well be accomplished without the aid of radically new materials. And although the realization of very much faster arithmetic circuits for computers may be retarded to some extent by the lack of suitable components, it is quite likely that a combination of clever circuit design and resourcefulness will permit existing materials to be utilized in such circuits.

The New Environment

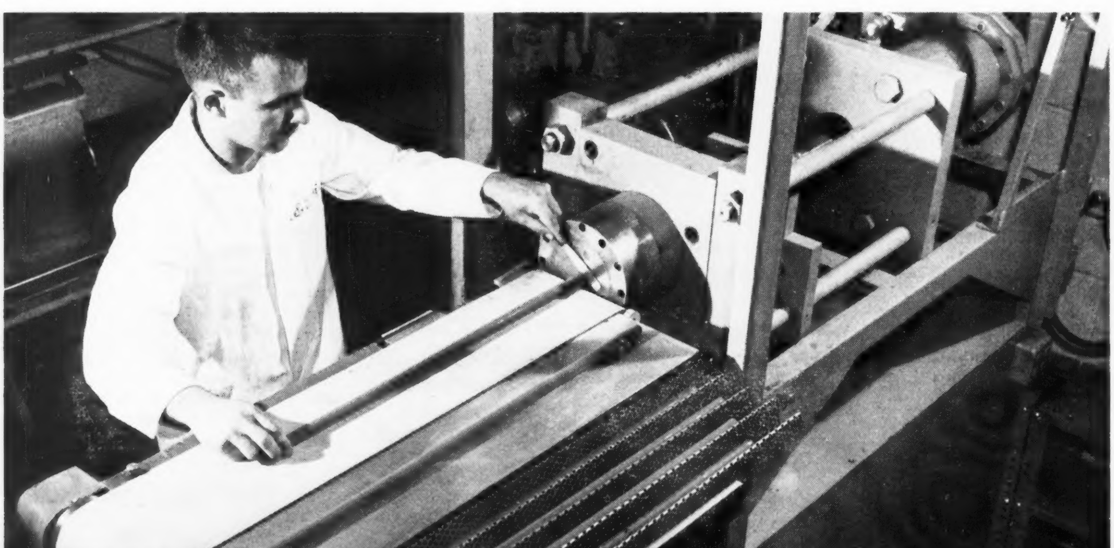
In a very real sense, electronic systems must perform in a new environment. Meteoroids are subject to collisions with the ions of outer space. These high-velocity encounters cause sputtering, the removal of surface atoms. The physicist and vacuum tube engineer have studied this effect for years and it is reasonably well understood. Sounding rockets were the first man-made systems subjected to this bombardment.

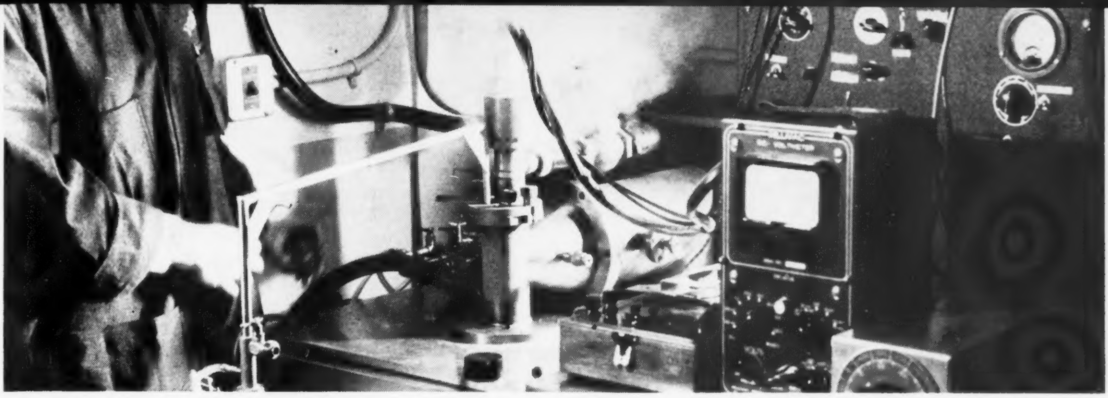
The new environment tends to invert previous experience, for high-vacuum or high-temperature regions are now "outside," whereas control and sensing subsystems are "inside." The new environment, then, is a situation not previously experienced by man except in a limited sense. It is distinguished by the fact that there is no "region of relief." For example, designers can no longer enjoy the luxury of confining various environmental factors within reasonably spaced isotherms or isobars.

An electronic device for a ground-based installation can be designed largely on the basis of its electrical characteristics alone. Such a device can be applied in a high-performance aircraft or space vehicle only if we are willing to pay the weight and power penalties exacted by environment control systems such as refrigerators.

It is clear that we cannot now afford this, nor will we ever be at liberty to construct regions of relief for the achievement of optimum local environments except for the protection of human beings. Regions of relief from high-temperature, nuclear,

This special extrusion press is used to fabricate experimental ferrite materials for use in missile electronic components.





Liquid helium is being placed in cryostat as part of study of basic properties of semiconductors over a wide range of temperatures.

high-vacuum and other effects are obtainable only at great expense to the mission of the system.

We now turn to two distinctly identifiable, but not always independent, generators of materials problems which we have labeled "functional multiplicity" and "qualitative multiplicity." A technique called "microanalogy," which often leads to a proper selection of materials for a given application, will then be described.

Functional Multiplicity

Functional multiplicity arises from the application of a material so as to perform two or more functions. An electrical resistor, for example, must not only impede an electrical current but must also dissipate the heat generated in this process.

One of the simplest of electronic components is the chassis on which is mounted an array of circuit elements and connecting conductors. Such a chassis must perform the dual function of maintaining the desired spatial relationships among the components and of dissipating the heat generated within the circuits. Either a steel or a copper chassis may serve under ordinary conditions.

If, however, we place the chassis in a relatively high-temperature ambient and impose a maximum weight requirement as well, the choice is no longer simple. It now requires a detailed knowledge of strength-weight ratios and thermal conductivities as functions of temperature. Such data are available for copper and for many steels, but in the absence of data, or under stringent requirements, a demand for a "new material" may arise.

Cathode materials are required to emit enormous numbers of electrons at exceptionally high temperatures while maintaining a very low equilibrium vapor pressure. In principle, this is no more difficult than the chassis problem. In reality, however, we do not yet have enough basic data for an optimum choice of material. The cathode materials of 1965 very likely exist today in adequate supply, but the complex data to permit their selection in the face of the functional duality of high-electron emissivity and low vapor pressure are not at hand.

The demands of functional multiplicity strain the laboratory facilities available to the materials technologist. Too often he is expected to limit his examination either to mechanical or electrical properties and to the restricted range of independent variables applicable to an immediate problem. It follows that a demand for new materials may be generated merely by the paucity of available data on existing materials.

Qualitative Multiplicity

Qualitative multiplicity, the second great generator of materials problems, arises when two or more materials must stand in proximity or in contact with one another. If, for example, we couple two materials of similar thermal expansivity in the fabrication of a metal-ceramic seal, we must reckon with the tendency of the metal and the ceramic to react and form low-strength compounds.

In general, qualitative multiplicity results from the requirement of functional multiplicity, as in the simple example of a solder connection wherein ease of bonding, low electrical resistance and high mechanical reliability stand coequal. In some applications, the thermocouple provides an example of qualitative duality and functional unity. Two different materials which in contact give rise to an e.m.f. must be welded together.

Many pairs of materials, over a given temperature range, are capable of yielding an e.m.f. of satisfactory magnitude. Unfortunately, in the given environment, the diffusivities of components of the two materials may well be important. Components or voids may form as diffusion takes place and these can result in the failure of the thermocouple.

Problems of qualitative (CONTINUED ON PAGE 106)

Recent developments in radar

Once essentially systems in themselves, radars today are being combined with flight vehicles as nearly inseparable components of complex weapon systems in which they are the sensing, and often the directing, element

By Leonard M. Barker
HEAVY MILITARY ELECTRONIC EQUIPMENT DEPT., GENERAL ELECTRIC CO., SYRACUSE, N.Y.

Leonard M. Barker is a specialist in systems engineering in the Missile Guidance Section of the Heavy Military Electronic Equipment Department of the General Electric Co. in Syracuse, N.Y. After graduating from the University of Nebraska in 1942 with a B.S. in mechanical engineering, he served four years as an officer in the U.S. Air Force with various radar and communication assignments. Since joining GE after World War II, he has been engaged primarily in the design and development of radar. He is presently engaged in developing the guidance system for the Atlas ICBM, and was responsible for preparing the original technical proposal given to the Air Force and, subsequently, charting the major phases of the development program.

RADAR has a prominent and vital role in weapon systems being developed in this astronautical age. It is essential for coping with the fantastic speeds of modern aircraft and missiles. Radar and flight vehicles are being combined as nearly inseparable, integrated elements of super-weapon systems in which radar is the sensing and frequently the directing element of the system. Thus we find radar being employed in precision guidance systems for ballistic missiles and in integrated defense systems deployed against weapons of this type, as well as against more conventional manned aircraft.

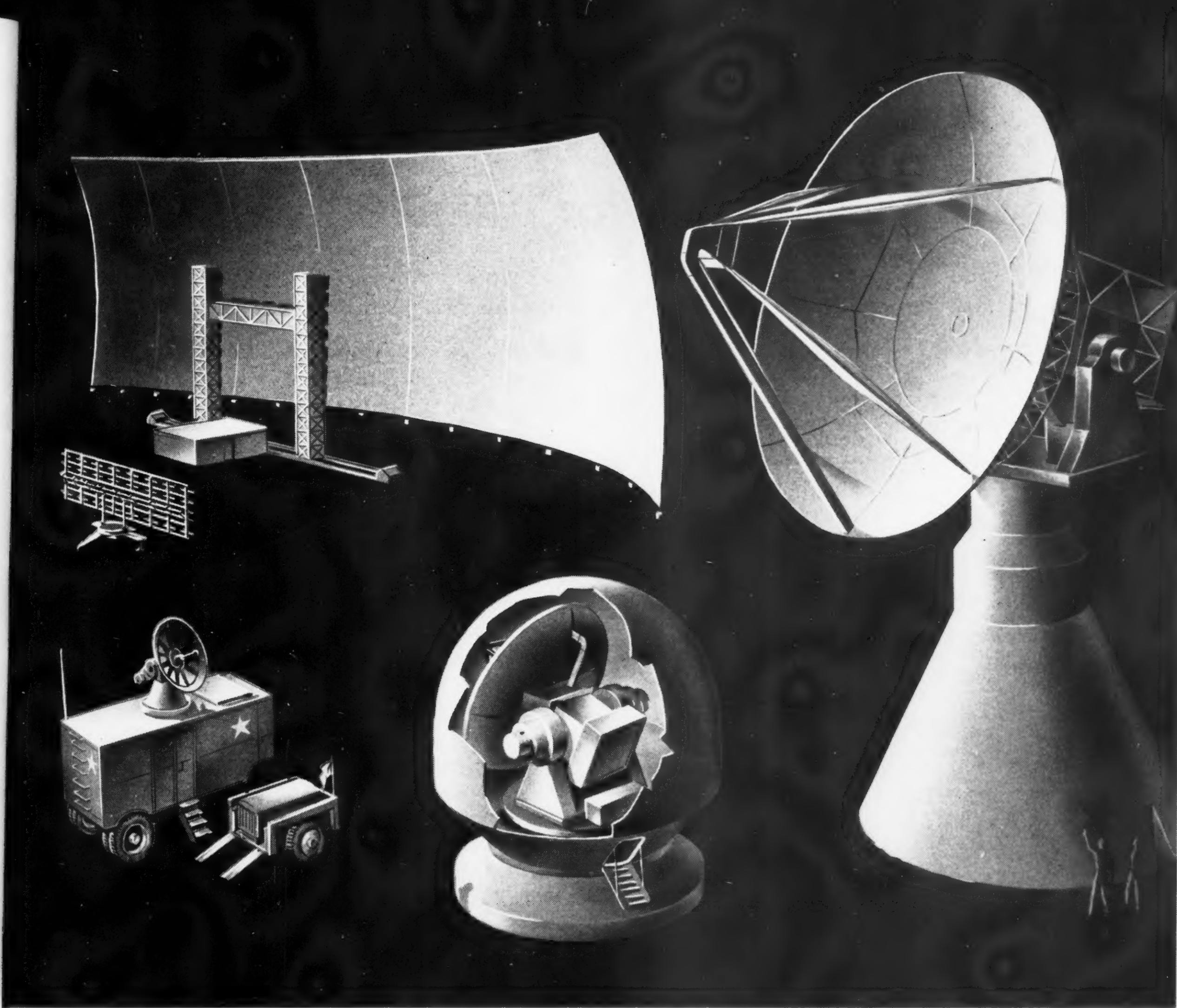
The most obvious trend in radar used for the detection and skin tracking of airborne targets is the enormous increase in the size of the RF components due to the ever greater need for higher radiated powers. Modern aircraft fly at more than twice the speed of their propeller-driven counterpart of yesteryear, covering twice the distance in a given time. Yet for many radar applications involving aircraft, RF power requirements have been multiplied by much more than even the factor of 16 implied by the radar range equation as being required for doubling the range of a radar.

Search radars, for example, usually must search out a volume of space to detect an oncoming target, and this takes time. The target may have been just out of range on one sweep. The actual detection range depends on how far the target can penetrate the search area before being illuminated on subsequent radar scans, i.e., on the speed of the target. Also, the time required for a target to traverse the distance from an outlying search radar to the area being protected is a function of target speed, so that ever greater ranges have been required of search radars in an attempt to retain sufficient warning time.

Solution Has Come Through Brute Force Techniques

Modern jet aircraft, with their sleek, sweptback silhouettes, present effective radar reflection areas of about one-tenth that of their propeller-driven counterparts, contributing another factor of 10 in the required radar power. Ballistic missiles only magnify these problems of the radar designer.

The solution to this need for huge increases in effective radar power has of necessity been accomplished primarily through the



Radar has evolved at a tremendous rate since World War II to keep pace with military requirements and the rapid advances in flight vehicles. WW II workhorses, such as the SCR584 track radar (lower left), have sired the extremely precise radar "theodolites" and giant reflection trackers of today (right). The SCR270 WW II search radar (upper left) has evolved into football-field size antennas and electronic scanners (top).

use of brute force techniques, such as employing football-field size antennas and ever larger transmitters. While this represents quite an engineering accomplishment in itself, it is not the sort of thing that attracts scientific interest. Moreover, there have been no popularized milestones along the way, comparable to the conquest of the sound barrier, for all to see.

Progress in radar has been made during the last decade by the combined effects of a myriad of small, pyramidal improvements and discoveries, rather than by the flashy breakthroughs that characterized radar's growth when it was in its infancy. It has been enhanced by many peripheral advances, notably those in the computer and data handling field. In total, these advances are impressive. They have permitted radar to keep pace with accelerated improvements in flight vehicles.

The radar design problem in recent times has been made much more difficult in other ways. The penalty for failure of a radar to perform its function is much more serious today—as serious as the destructive effects of a hydrogen warhead, the loss of a costly intercontinental ballistic missile or its target, perhaps as serious as the loss of national and individual freedom.

The trek to progressively higher operating frequencies which characterized radar development during World War II, and extended into the postwar era, has been reversed for many long-range radar applications. The reasons are simple. Much of the huge deficiency in effective radar power had to be made up by increasing the size of the antenna. Larger antennas (CONTINUED ON PAGE 67)

Radio techniques for missile guidance

This look at the principles and problems of modern radio techniques suggests the foundations on which future astronautical guidance systems will be based

By Eberhardt Rechtin

JET PROPULSION LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY, PASADENA, CALIF.

Born in Orange, N.J., in 1926, Eberhardt Rechtin received his B.S. in Electrical Engineering at the California Institute of Technology in 1946 and his Ph.D. from the same school in 1950. Winner of a Westinghouse Science Talent Award in 1943, Dr. Rechtin was a Cole Fellow in 1947 and a National Science Fellow in 1948. He has been employed at Jet Propulsion Laboratory since 1949, becoming chief of the Electronics Research Section in 1954 and chief of its Guidance Research Division last year. He has made important contributions in the fields of radio propagation, noise and filter theory, missile guidance, secure communication systems and countermeasures, and also played a major role in instrumentation of the Explorer satellites.

ROCKETS have the well-known advantage over conventional shells of not requiring a gun barrel. But throwing away the barrel also means throwing away the close trajectory control necessary during the violent period of propulsion. Missile guidance replaces the metal gun barrel with electronic trajectory constraints. Of all the methods of guidance, the radio method is certainly the most flexible. Because guided missiles are necessarily designed very close to maximum performance margins, the adaptability of radio techniques can be used to good advantage in mating the other parts of the missile system: The propulsion unit, the aerodynamic control devices, the servo control system and the autopilot.

The simplest use of radio is to send information on internal missile performance to a remote observer. Despite its simplicity, such telemetering (literally, "the sending of measurements") has proved so essential in the design of missile guidance systems that it is often retained as a monitor on the final models of weapon systems.

Tells Missiles How to Maneuver

It is equally possible to send information in the other direction, i.e., from the observer to the missile. Using this link, the observer (the "base" in automatic systems) can tell the missile how to maneuver to accomplish its objective. In case of serious trouble, such a link can also be used to command the missile to destroy itself.

The next most complicated radio technique is direction-finding. Through careful listening procedures, an observer can tell the direction from which radio waves are arriving. There are literally dozens of different ingenious antenna designs for measuring the radio direction of arrival. Each design is carefully tailored for a particular application in reliability, simplicity, accuracy, size and mobility. Missiles seeking moving targets often use direction-finding techniques coupled with lead-angle computers in the same way that a safety man on a football team tries to intercept a runner with the least expenditure of energy and time.

A third technique uses radio to measure the time it takes for radio waves to travel from one point to another and thus determine distance. The most common method is to transmit a signal and then wait for an echo or reply. The echo technique is commonly called radar ranging; the reply technique, beacon ranging. The measurement can be made from either the missile or the base. A consider-

ably more complex system uses a network of receivers with a single transmitter. The network of receivers is one form of radio interferometer. A related system employs a single receiver and a network of transmitters. This configuration is widely used in navigation applications (Loran).

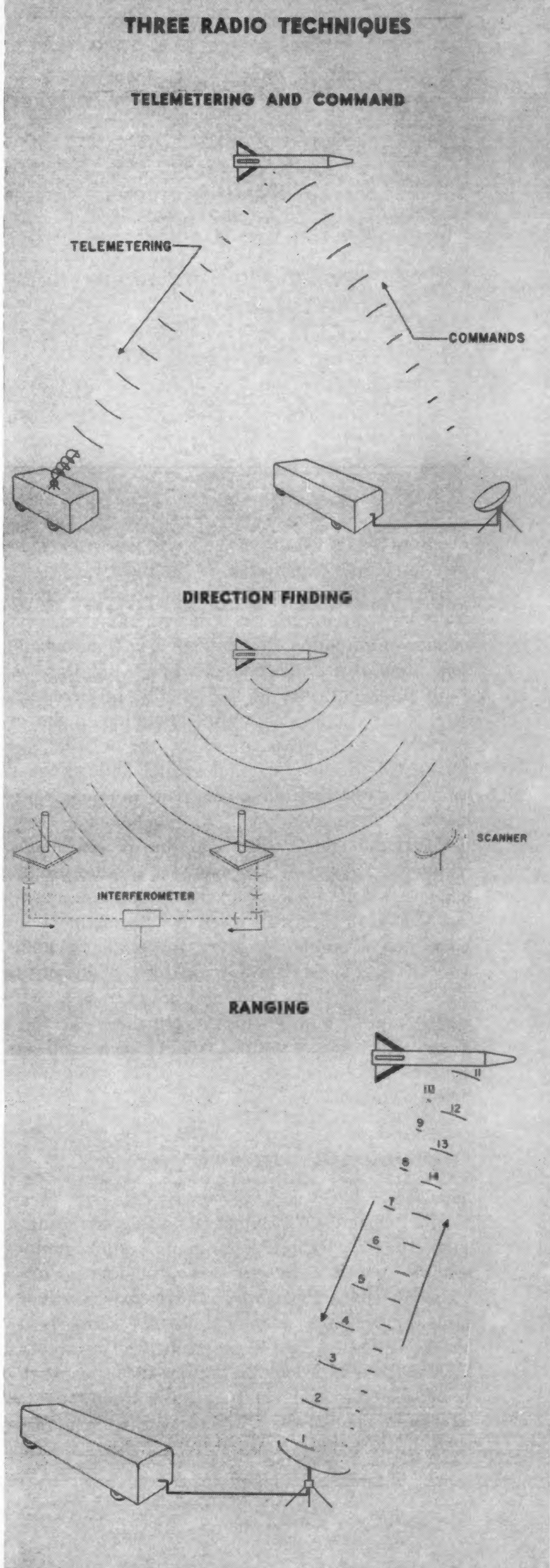
Most radio guidance systems use a combination of internal measurement, command, direction-finding and ranging. The particular combination depends strongly on the mission and the requirements of the rest of the missile system. But rather than attempt a survey of the many different schemes in use today (on which appropriate decisions have been made anyway), let us study the fundamentals of missile radio guidance as raw material for future designs. The two principal functions of radio techniques are making measurements and generating commands. We shall consider each in turn.

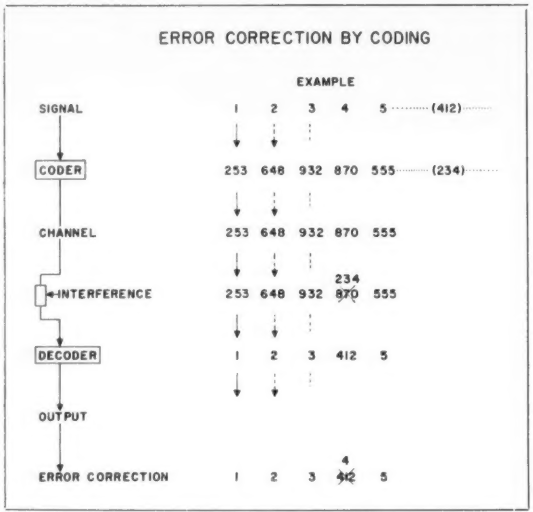
Measurements by Radio

It is the function of a missile to carry a payload from one place to another. As one missileman puts it, the missile is a truck. The principal problem of truck drivers is knowing where they are and where they are going. The problem sounds simple enough when truck drivers are involved; the missile designer's problem is to do the same task without the driver. In some applications, the target destination is also moving and quite often is attempting to get out of the way.

One of the finest and most practical ways of determining missile (and target) location relative to a base point is by radio probing. Probing is a try-it-and-see process. A radio wave is sent out into space and the effects are observed. The technique is used in many different ways. The radar listens for echoes. The beacon tracker listens for a reply. The beam-riding missile notes on which side of its own path the radio energy was the strongest. The Loran-following missile listens to a group of synchronized transmitters and determines the relative times of arrival from each. The homing missile listens for telltale target radiations. If the observed effects disagree with the anticipated effects, corrective action, in the form of guidance, is taken.

If transmission distances were comparatively small, if no interference were expected and if large amounts of primary power were available, radio probing would be simple. The sophistication in radio probing which almost all missile guidance systems require is a direct result of long distances, deliberate enemy interference and very limited primary power in the missile. Part of the most elegant theory of communications—information theory—has been derived and applied to the radio probing problem. In addition, some of the best





electronics engineering in the world has been necessary for proper exploitation of the theory.

Theory, for example, demands that energy be used only to determine new information, not to reconfirm information already known. Electronic engineering, as a direct consequence, is hard-pressed to build highly stable and highly precise radio equipment capable of proper operation in the extremely rugged environment of the missile. Information theory also states that only a small amount of information is necessary to guide a missile to its destination.

Using the quantitative definition of information as a measure of the performance of a radio probing scheme, we find that most of the otherwise appealing schemes concern themselves with far more "information" than is necessary for guidance alone. Indeed, one of the most valuable results of the theory has been to show the existence of a well-defined optimum in system performance. Even if a presently practical system cannot reach such performance, the optimum provides an effective standard for comparison.

Interference Considered Further

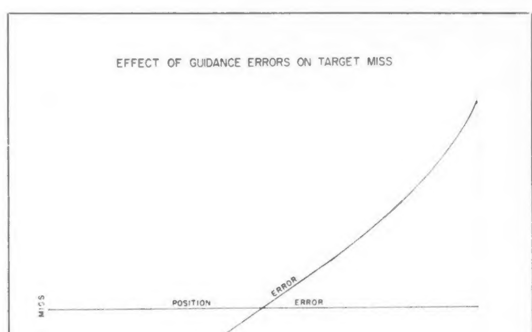
The interference problem is worth considering in more detail. There are many radio probing schemes which work very well providing no interference is present. Under interference conditions, however, accuracy and reliability are seriously degraded. The enemy is generally well aware that missiles pose a serious threat and that some action is necessary to combat them. Electronic countermeasures against the radio measuring system are comparatively inexpensive even when designed with a sophistication comparable to the missile radio system.

False echoes and replies, for example, are easily generated. Considering the cost of letting a missile achieve its goal, the enemy is perfectly willing to apply large amounts of power as jamming. Information theory is applied by the enemy as well! Thus what started out as a straightforward problem in radio instrumentation has evolved into a difficult problem in game theory. Needless to say, the game is not over. With the risks being what they are, the game is too deadly for either side to stop.

For readers with a more scientific than military turn of mind, the problem of interference takes on a different aspect. Interference—noise—is the real limit to precision guidance of rockets to the moon and the planets. Signals finally get so weak due to the extreme distances that the output of the receivers consists principally of an amplified version of the receivers' internal noise. Techniques are slowly being evolved to combat the interference, but the obstacles are formidable. At present, it is practical to probe to the moon (0.24×10^6 miles); it is marginal to signal back from Mars (100×10^6 miles); but the nearest star is a long way away (10^{14} miles).

Several Approaches Can Be Used

There are several approaches which might be taken to solve the problem. It is a well-known fact that we can read through more interference by slowing down the information rate. If we listen long enough, we can detect a steady signal in a surprising amount of noise. However, the approach is limited. If we can detect a beacon signal from the vicinity of (CONTINUED ON PAGE 112)



Missile guidance by infrared

Small, simple and employing relatively few electronic components, IR devices, already playing a major role in missile tracking systems, are now being applied toward the solution of a large variety of guidance problems

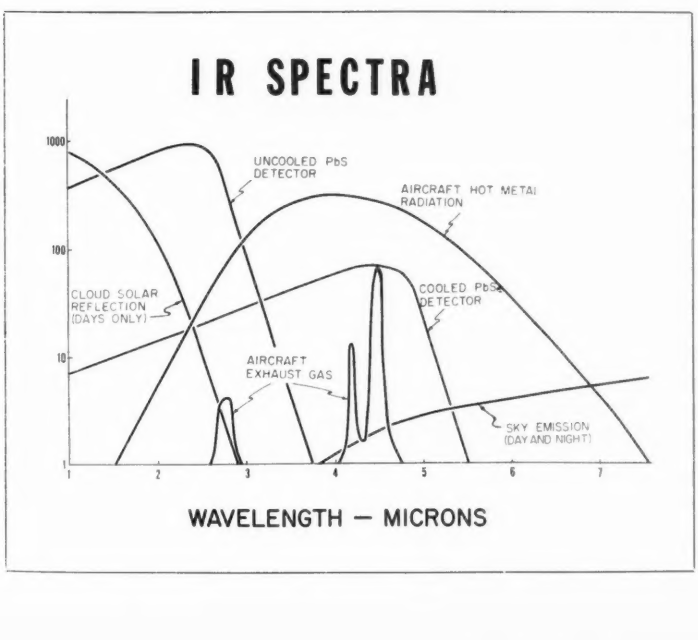
By Raymond H. McFee

AVIONICS DIVISION, AEROJET-GENERAL CORP., AZUSA, CALIF.

WITH THE high degree of development of radar systems for the detection, tracking and ranging of target objects, the question naturally arises: Why the interest and increasing application of infrared for the detection of military targets? Although infrared radiation has trouble penetrating clouds, and many other things surrounding the target may also radiate copiously in the infrared region, modern high-altitude aerial operations allow effective use of infrared detection devices in several applications.

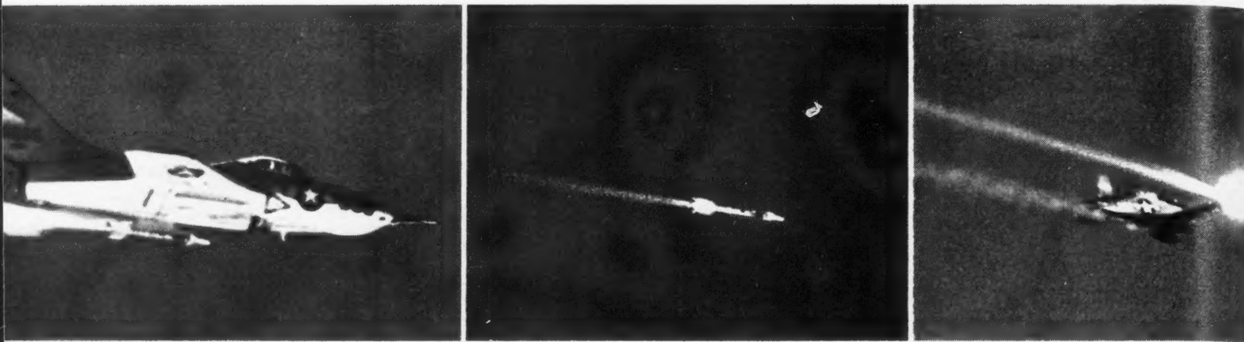
Close on the heels of the development of radar techniques has come a variety of countermeasure (ECM) schemes which can reduce the effectiveness of microwave detection systems to a considerable degree. Since infrared detection devices operate from the natural radiation emitted from the target, rather than from radiation reflected from the target, the source of detectable radiation, in cases of targets of military interest, is difficult to simulate or decoy.

An attractive feature of infrared devices in general is that they are small, simple and have relatively few electronic components.



Raymond H. McFee is presently director of research for the Avionics Div. of Aerojet-General Corp., Azusa, Calif. In this capacity, he supervises the company's research activities in infrared, which include analysis and basic development of IR devices, optics and radiation measurements. After obtaining his Ph.D. in physics from MIT in 1943, Dr. McFee was engaged for 12 years in various phases of infrared research and development, 10 years of which were spent with Electronics Corp. of America, where he was director of research. He assumed his present position at Aerojet-General in 1956.

(*U.S. Navy photos*)



Infrared guidance in action. Sidewinder with IR tracker is shown being fired from attacking aircraft and hitting flare pad on wing tip of target drone.

Many IR devices can obtain sufficient useful information from the target while employing detection packages under 6 in. in diam. Since fundamental limitations on angular resolution capability are related to the size of the optical aperture as compared to the wave length of the detected radiation, IR devices can obtain much higher resolution with small apertures than can a microwave device.

The infrared region of interest for detection of airborne targets is confined to wave lengths between one micron and five microns ($1 - 5 \times 10^{-4}$ cm), which is 1000 to 10,000 times smaller in magnitude than wave lengths used in radar equipment. This feature of high angular resolution has made IR devices particularly useful as tracking systems for fire control and target seekers. The angular information given by IR trackers is steady and smooth, and lends itself well to electronic computation.

Although good angular information is obtained by the infrared detection system, data on the range of the target are not so readily gathered by this technique. As a consequence, IR systems are generally used where only angular position or rate of change of angular position are needed. Combination systems, where IR devices which supply precise angular information are employed together with range-only radars, are coming into active consideration.

Among those systems which operate successfully on only angular information are tracking systems for guided missiles. Missiles can be guided simply by maintaining their flight path in a given orientation with respect to the direction from the missile to the target. For example, if the missile is always kept pointing directly toward the target and made to travel fast enough, an eventual collision will occur. This tactic is called pursuit-course guidance. The problem to be solved by the guidance system is simply to maintain the line of sight as seen by the tracker coincident with the missile axis. Deviation from this condition produces error signals from the tracker which are fed to the control fins for correction of missile heading.

Except in the special case of the missile following directly in the path of the target, the pursuit-course trajectory will not be a straight line. Consequently, power must be expended for maneuvering the missile in the curved path required. In the technique called collision-course guidance, illustrated on page 35, the projected point of collision is determined, and the missile is kept aimed toward this point. In the situation shown in the drawing, a non-maneuvering target will be at point A at time t_0. At the same time, the missile is expected also to arive at A. At time $t_0 - 1$, target and missile will be at B and B' respectively, while at time $t_0 - 2$, they will be at C and C'.

Missile Will Follow Collision Course

From the geometry of the situation, it can be seen that if both flight paths are straight lines, the triangles formed by points ABB' and ACC' are similar, as are all triangles formed by the instantaneous positions of target and missile with the collision point. This means that the line of sight from the missile to the target always bears at a constant angle from the missile's flight line. Conversely, if the angular velocity of the line of sight from the missile is maintained at zero, the missile will follow a collision course.

It may be noticed that the range between missile and target is not required to compute the collision course. The infrared tracker is thus readily adapted for collision-course guidance by employing a detection system which produces error signals proportional to the angular velocity of the line of sight. The tracker is used to maintain coincidence between the tracking line (extension of the optical axis of the tracker) and the line of sight. The rate at which the tracker is reoriented to maintain coincidence is then utilized as the error signal. By

adjusting the flight path until the condition of constant bearing of the sight-line is met, the collision course is established.

The basic functional requirement of the infrared guidance system is to detect and provide continuous information on the angular position and/or angular velocity of the line of sight to the target which is located at a tactically useful range. This information must be available with adequate reliability under as wide a variety of operational conditions as possible. The problem of the infrared designer in providing maximum over-all capability of the missile guidance system is to make effective use of the advantages of the IR technique while avoiding the restrictions set by the limitations of this method.

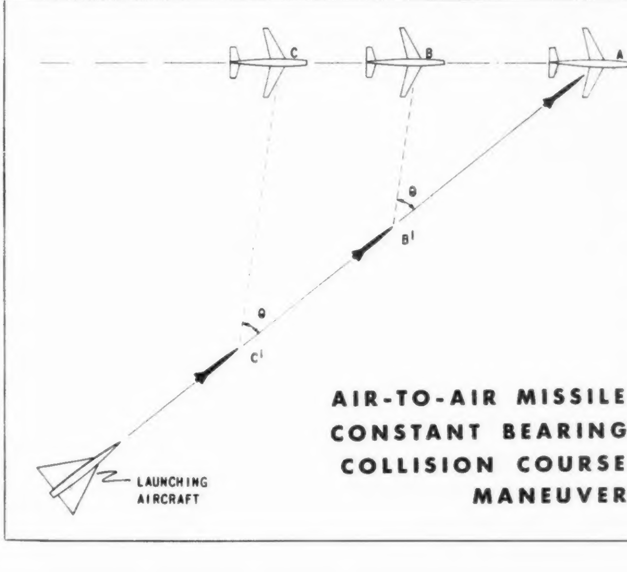
The design problem, then, is to obtain an unambiguous radiation signal from the target in the presence of a background which may also radiate in the infrared region. This problem in turn resolves into two areas. The first is that of providing adequate sensitivity of the device to the radiation from the target so that tracking may take place at adequate ranges. The other aspect is one of discrimination against the unwanted radiation from the background in favor of the target radiation.

With respect to the sensitivity problem, this requirement is, of course, related directly to the quantity of radiation emitted by the class of targets of interest. A chart showing IR spectra will be found on page 33. In the case of the most highly developed IR missile guidance application, the air-to-air missile, the targets are primarily jet aircraft of various sizes. The most copious source of radiation from such aircraft is the hot tailpipe of the engine, which is exposed in the aft direction. The heated metal parts radiate with a spectrum characteristic of blackbody emission. At representative operating temperatures, tailpipe radiation peaks in spectral distribution at approximately 3.5 microns, with ample energy emitted at wave lengths on either side of this peak. In addition, turbojet-powered aircraft provide IR radiation from the hot gases in the jet plume. These gases are usually rich in water vapor and carbon dioxide, both of which emit IR energy when heated to high temperatures.

Radiation Varies

The magnitude of the available radiation varies, of course, with the size and number of engines on the target aircraft. Because of the masking effect of the structure of the target aircraft, the apparent radiation varies considerably with viewing aspect. Since the infrared tracker is located at a considerable distance from the target, the radiation must pass through an appreciable quantity of atmosphere.

The air is not perfectly transparent at all wave lengths in the IR region, and, in fact, absorbs very actively at several points in the spectrum. As a result, the spectrum distribution of the target radiation reaching the missile tracker will be strongly influenced by the absorption of the intervening atmosphere. Under atmospheric conditions of haze or smoke, a certain amount of scattering of transmitted radiation will occur. The magnitude of the scattering is considerably less in the IR spectrum than that which occurs in the visible, due to the longer wave length of the radiation. Atmospheric objects such as clouds and (CONTINUED ON PAGE 110)



AIR-TO-AIR MISSILE CONSTANT BEARING COLLISION COURSE MANEUVER

Hughes GAR-2A Falcon missile (left), using lead sulfide infrared seeker for guidance, complements GAR-10 Falcon (right) which employs radar guidance.

Some problems in radio telemetry

While considerable progress has been made during the past few years, three major problems appear to require effort on a broad front: Long-distance telemetry from missiles and satellites, frequency allocation and reliability

By M. H. Nichols and L. L. Rauch

UNIVERSITY OF MICHIGAN, ANN ARBOR, MICH.

Rauch Nichols

The paths of Myron H. Nichols and Lawrence L. Rauch, co-authors of the standard textbook in the field of radio telemetry, have crossed many times during their careers. At present, both are professors of aeronautical engineering at the University of Michigan.

Dr. Nichols returned to the university last year after three years with Ramo-Wooldridge Corp. working on ballistic missile systems problems. He had previously been at U. of Michigan from 1946 to 1949 and from 1951 to 1954. He has also taught at the California Institute of Technology and Princeton University. His main areas of interest, in addition to telemetry, are guided missiles, thermionic emission, upper air meteorology and instrumentation engineering.

Dr. Rauch has been at the university since 1949 and since 1952 has been chairman of its instrumentation program. His background includes eight years at Princeton as fellow, research assistant and instructor. He has worked as a research supervisor on radio telemetering systems for aircraft and was supervisor of air blast telemetering at Operation Crossroads in Bikini in 1947–49. An Air Force consultant since 1949, his primary fields of interest are radio telemetry and information theory, and dynamics of non-linear systems.

INCREASING requirements for remote metering of various functions in missiles, aircraft and satellites have focused attention on a number of problems in radio telemetry today. Among these are such problems as reduction of space and weight of airborne telemetry gear; improving performance under service environmental acceleration and temperatures; improving compatibility between instruments and the rest of the telemetering system; data reduction; etc.

Much progress has been made over the last few years in the application of solid state elements to airborne circuitry, with resulting improvements in ruggedness, reduced power consumption, weight and space, etc. Also, data reduction systems have been developed and assembled which materially reduce the time and man-hours required for data processing, although they do not eliminate the need for human judgment in editing the records.

As the authors have pointed out before (*Radio Telemetry*, 2nd edit., John Wiley & Sons), there still remains considerable room for improvement in instrument development from the point of view of increased compatibility with the rest of the telemetering system, and ruggedness and stability of calibration.

At the moment, however, three major problems appear to require effort on perhaps a broader front than those mentioned above. These are:

1. Problems related to long-distance telemetering from missiles and satellites
2. Frequency allocation
3. Reliability

Long-Distance Telemetry

Flight testing of intercontinental and intermediate range missiles has placed range requirements up to several thousand miles on the radio telemetering link between the missile and ground stations. (When telemetering from ICBM nose cones is required during re-entry into the atmosphere, structural and propagation problems tend to limit the signal strength available at the receiver. In this respect, the problem at the receiver is similar to the long-range telemetering problem.)

Telemetering (and communication) from satellites and space

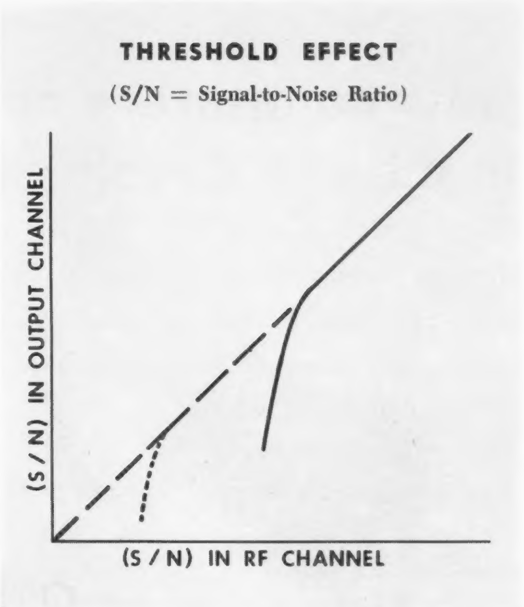
ships will also pose the problem of radio transmission over long distances with minimum allotted transmission power.

Five possible ways of improving the range, for a given required information capacity, immediately come to mind. These five methods are discussed briefly below.

1. *Increase radio transmitter power.* Radio transmitter power is limited by the space and weight allowed in the vehicle for the radio transmitter itself and for the primary power supply. Even in large ICBM's, the weight must be carefully considered because of the strong dependence of range on inert take-off weight. In satellite vehicles, the weight problem is more serious and, unless solar power sources or other sources of large energy-to-weight ratio are available, the longer time periods over which telemetering is required present serious power supply problems.

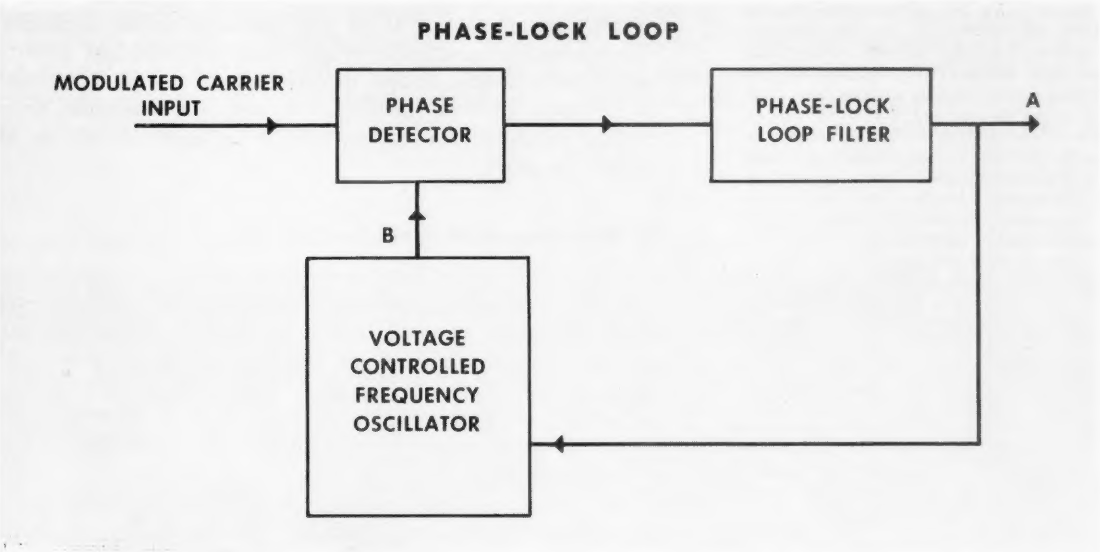
Then, too, higher peak power into wave guides and antennas always presents more complicated problems in suppressing arcing and corona, as well as interference with other equipment. We are already using average powers of the order of 100 watts for large missile telemetering, and it is unlikely that another order of magnitude increase will be practical in the foreseeable future.

2. *Increase the directivity of the transmitting antenna.* Wherever possible, directive transmitting antennas may be used to improve the signal strength at the receiver. There are obvious limitations to this method during flight through the atmosphere and in pointing the antennas in the proper direction. Unless the attitude of the vehicle is accurately controlled so that antenna pointing can be programmed,



some sort of beacon must be provided on the ground by means of which the transmitting antenna can orient itself.

For example, a transmitting antenna "dish" 60 ft in diam operating at 2000 mc will produce an increase of signal strength, over an isotropic radiator, of about 50 db, i.e., five orders of magnitude of increased power, at the receiver when properly pointed. This represents an equivalent increase of range of $2^1/_2$ orders of magnitude. The beam width would be 0.5 deg. (CONTINUED ON PAGE 98)

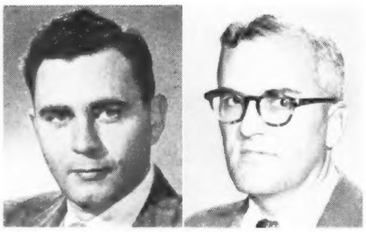


How computers and simulators aid in missile development

Electronic equipment of this type is growing more and more important in the four basic phases of development work—preliminary analysis, design, component and subsystem testing, and complete system testing

By Irwin Pfeffer and George P. West

SPACE TECHNOLOGY LABORATORIES, A DIVISION OF THE RAMO-WOOLDRIDGE CORP., LOS ANGELES, CALIF.



Pfeffer West

Irwin Pfeffer received his B.E.E. from the Cooper Union School of Engineering in 1948 and his M.S. in electrical engineering from Cal Tech in 1949. From 1951 to 1954, he was with Hughes Aircraft Corp., specializing in analysis and simulation in the control field. He joined Ramo-Wooldridge in 1954 and now heads the analysis and simulation section of the newly formed Space Technology Laboratories. He has had nine years of experience in control systems, network analysis and noise theory.

George P. West received his B.S. in electrical engineering from the University of California in 1942 and his M.S. in mathematics from Stanford in 1949. A radar officer in World War II, he worked in computation and simulation at NACA Ames Aeronautical Laboratory from 1949 to 1952, and later headed computation groups at California Research and Development Co. and General Electric's advanced electronics center. He joined R-W in 1954 and is now manager of the Space Technology Laboratories Data Analysis Dept.

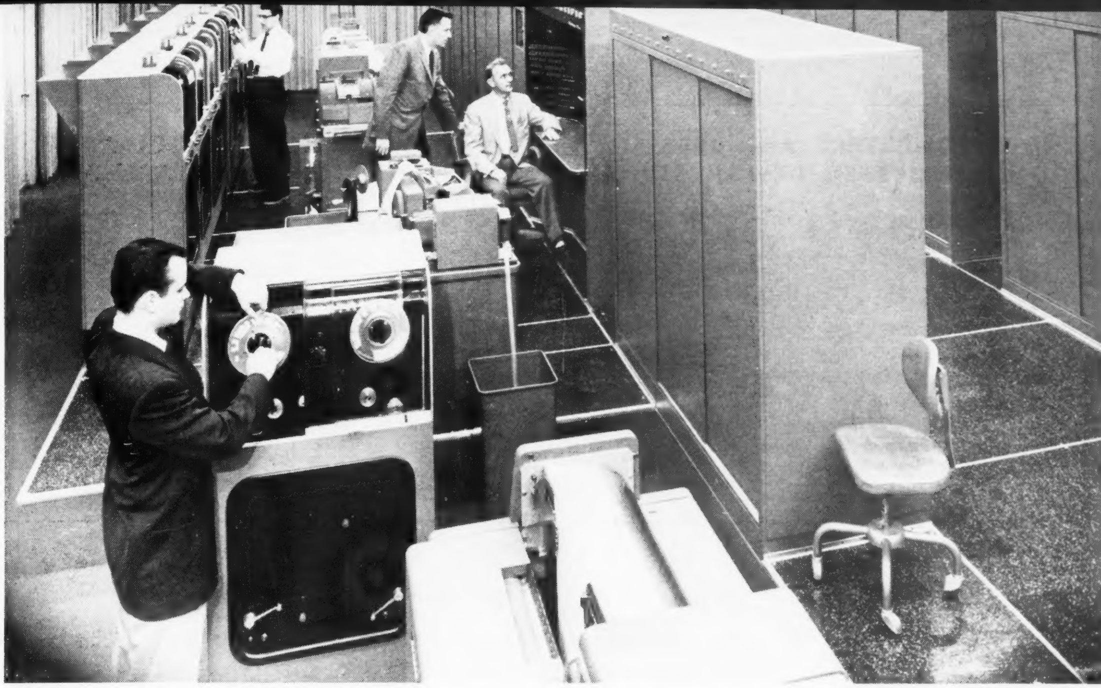
ONE OF the most fruitful applications of electronic computers to the problems of modern science occurs in the field of guided missile technology. It is not overemphasizing the case to state that the development of an effective long-range ballistic missile system would be impossible without the use of electronic computers. The problems encountered in such diverse fields as propellant chemistry, propulsion design, thermodynamics, control system testing, and complete system testing. In each of these long-range guidance frequently does not yield to the methods of pure analysis. In such cases, machine computation is mandatory if an optimum solution, or indeed any solution, is to be obtained.

Missile development can be conveniently divided into four basic phases: Preliminary analysis, design, component and subsystem testing, and complete system testing. In each of these phases, computation and simulation play an important role, but perhaps it is in preliminary analysis and design that the most dramatic contributions are made. The basic feasibility of a particular approach may be demonstrated using the computer; a missile system may be sized and exchange ratios established between such parameters as weight, range and accuracy; an error analysis of a navigation system may indicate the guidance complexity required for a specified accuracy; or a non-linear, time-varying missile control system may be designed directly on an analog computer.

Reduces Amount of Flight Testing

In the component and subsystem testing phase, actual pieces of hardware are operated in a realistic, simulated environment, using an analog computer to "close the loop" around the piece of equipment under test. In this process, known as physical simulation, the analog computer solves the dynamic equations of motion, and therefore simulates the portion of the system external to the equipment under test.

The amount of flight testing, sometimes unreliable, usually destructive and always expensive, is greatly reduced. Physical



Preparing a problem for the 1103A digital computer. Tape reel being placed in Uniservo in rear will be read into computer memory to set up program and supply data for problem. Tape reel in foreground, containing answers to previous problem, will be printed out on high-speed printer in extreme foreground.

simulation is also an integral part of the design phase, since important redesign may result from tests on a prototype piece of equipment in a simulated loop.

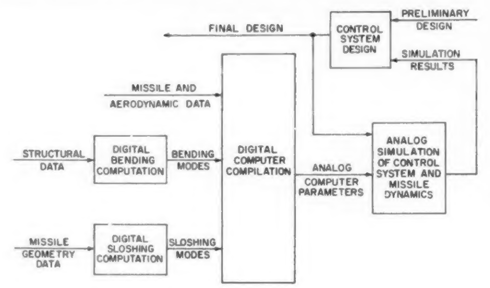
In the complete system testing phase, electronic computers play an essential, if not always glamorous, role as an indispensable tool in data reduction and analysis. Evaluation of massive flight test data, for example, may be facilitated tremendously by use of automatic computer techniques.

Computation may be described as a mathematical and/or logical process yielding a numerical solution to a particular problem. Simulation is the process of representing a physical system, on a one-to-one basis, by a laboratory model whose characteristics are easily manipulated and whose performance is easily measured. When the laboratory model happens to be an electronic computer, simulation indeed becomes one form of computation. Neverthless, a useful distinction is still commonly made between simulation and more abstract mathematical computations, such as matrix inversion or the solution of non-linear algebraic equations. The latter are almost exclusively the domain of the digital computer.

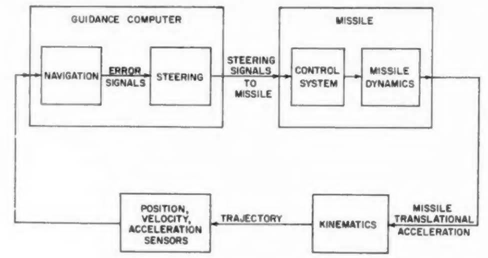
True simulation is an analog function, since the digital computer cannot, strictly speaking, establish the necessary one-to-one correspondence between its elements and those of the system being simulated. Despite this, the digital computer may be programmed to solve dynamic systems in a manner closely akin to simulation, provided one does not inquire too deeply into internal details of the computation. This process is called digital simulation.

Analog computing center at Ramo-Wooldridge. This facility has six operating stations, 400 operational amplifiers.

HOW COMPUTERS ARE USED IN CONTROL SYSTEM DESIGN STUDY



BALLISTIC MISSILE GUIDANCE AND CONTROL SYSTEMS



One important application of digital computation is the approach employed at Space Technology Laboratories in attacking the missile sizing problem. Briefly, the problem of sizing a missile is that of specifying missile design parameters, such as initial weight, engine thrust, etc., in such a way that the missile is capable of achieving specified performance objectives. The problem is extremely difficult for several reasons.

First, there are a great many parameters which must be specified before the missile's performance can be evaluated. Furthermore, these parameters interact strongly with one another in a manner which is not easy to evaluate. Step-by-step optimization of the parameters of each subsystem will not yield an optimum design of the entire missile system.

For example, a change in the slenderness ratio (ratio of missile length to diameter) affects drag, which modifies the trajectory and required tank pressure. This affects tank wall thickness and weight of structure, which changes the aerodynamic heating, pressure program, allowable stress, trajectory, etc. In brief, the computation system must allow all the factors selected for study to interact properly with one another *simultaneously*.

Starting with given input variables and parameters, together with initial estimates of other specified parameters, the computer performs a weight balance, trajectory calculation, propulsion system analysis, tank weight analysis, pressurization computation, skin heating and tank thermodynamics computation, drag and lift analysis, control system and bending moments analysis and finally a study of weights associated with the pressurizing gas system.

At this stage, new values of all unspecified variables and parameters exist and the entire process is repeated until the new set of problem variables agrees with the previous set. A consistent set of system parameters and (CONTINUED ON PAGE 128)

Running a problem on the 704 digital computer. Unit in center, known as main frame, contains operating console, arithmetic unit and magnetic core memory.

Effectiveness of computers in flight simulation is increased by addition of this Addaverter, basically a translating device linking digital and analog computers.

Cures for which there are no diseases

In which an electronic engineer wonders if instrumentation experts aren't hypochondriacs who may be suffering from ataxia transduceria

By Martin L. Klein

COHU ELECTRONICS, INC., SAN DIEGO, CALIF.

ABOUT FIVE YEARS ago, the average data user was satisfied if he could obtain information good to 1 per cent. Three years ago, we were struggling to design systems good to 0.1 per cent. Today these are common, and we look forward to increasing the precision of amplifiers, systems, etc., to one part in 10,000.

At the same time, the amount of data being taken has increased tremendously. Back in 1950, most data users were satisfied to obtain information from 20 or 30 places at one time. Today we hear of tests being made where 400 data points taken simultaneously are not uncommon. Two significant steps: (1) Demand for higher and higher precision, and (2) demand for more and more data points.

And now the push is on for systems—very expensive systems—which maintain precision not far removed from the primary ones of the National Bureau of Standards.

Designer Meets Brunt of Demands

Let's look at an example of the problems confronting the instrument and electronic designer who bears the brunt of these demands. Some seven years ago, dc amplifiers good to 1 per cent were widely used, even in basic research. The instrumentation people then demanded a higher-precision amplifier. After a struggle lasting many years, a 0.1-per cent dc amplifier was brought out which had only one input referred to ground. But it developed that the instrumentation people were losing data not through the amplifier, but through the extensive land lines on their equipment. These land lines delivered information nowhere near as good as 0.1 per cent, and cluttered with noise, 60-cycle and other spurious data, which the new amplifier reliably and accurately amplified.

The instrumentation people came back to the amplifier designers and said, "We think this can be done if you only unground the input." The 0.1-per cent amplifier was then redesigned with what is called a floating input, in which noise can come over both ends of the lines at one time but the amplifier will not see it. Now it happened that the amplifier was played into grounded equipment; the immediate benefit of floating the amplifier was lost the minute it was connected.

About a year ago, the instrumentation people came back and said, "What we meant all along was that we (CONTINUED ON PAGE 117)

Martin Klein is director of the research division of Cohu Electronics. He served in the Navy in 1944–46 after receiving a B.S. in physics from Pennsylvania State University, and received his Ph.D. in physics from Boston University in 1951. Before joining Cohu, he was associated with Stancil-Hoffman and Rocketdyne. Dr. Klein is the author of some 50 published papers and two texts on electronics, and holds 17 patents on electronic devices. Two years ago, as an avocation, he originated a television science program called "Adventure Tomorrow," which appears weekly in Southern California.

Data processing in air defense systems

A computer with a large attention span and the ability to convert a multitude of problems into individual problems is the heart of the SAGE system, a system which could be adapted for use in anti-missile defense

By George E. Valley

CHIEF SCIENTIST, UNITED STATES AIR FORCE

George E. Valley has been intimately connected with MIT's Lincoln Laboratory since its inception in 1949, and from 1953 to 1957 was its associate director. In this capacity, he played an important role in development of the Air Force SAGE system. Dr. Valley was a national research fellow in nuclear physics at Harvard in 1940–41 and during the war became project supervisor and a member of the senior staff of MIT's radiation laboratory. He was appointed assistant professor of physics at MIT in 1946 and is now a full professor. Dr. Valley was a member of the AF Scientific Advisory Board from its inception in 1946 until 1955, and last year was appointed Chief Scientist of the Air Force.

ASSIGNMENT and control of high-performance weapons like ground-to-air missiles and modern interceptors constitute one of the basic problems of air defense. The effectiveness with which enemy bombers or missiles can be spotted, identified and destroyed obviously depends on the speed and accuracy of the information processing and ground control system for such weapons.

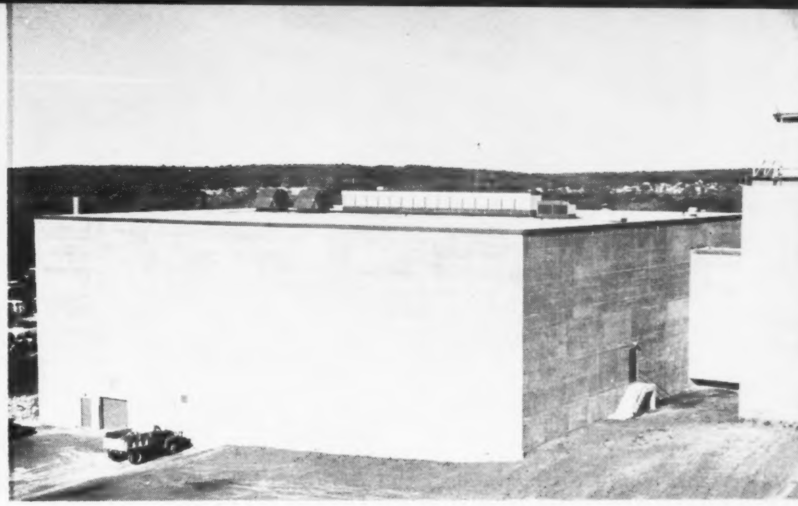
To understand the operation of any defense system such as the Air Force Semi-Automatic Ground Environment (SAGE) system, it is first necessary to know a little about the nature of the problems involved.

There are basically two different kinds of problems in information processing in air defense systems and ground control of flying weapons. In the first, and simpler, problem, only two objects are involved—the enemy bomber or missile, and the interceptor or missile sent up to knock it down. The second, and much more sophisticated, problem involves a multitude of objects—perhaps as many as a hundred enemy bombers or missiles and an equal number of interceptors or missiles to go after them.

In the first instance, the problem can be handled by a man, perhaps employing some mechanical aids in the form of radar and a relatively simple computer. In the second case, however, man is simply not equal to the task of keeping track of some 200 objects ranging over a wide area, and needs the assistance of a mechanical "brain," typified by the SAGE system, if effective defensive measures are to be taken.

Where it all starts—at long-range search radar stations, like this one at South Truro, Mass.

Gigantic size of AN/FSQ-7 air-defense computer, most important element in SAGE system, is indicated by this view of Building F, MIT Lincoln Laboratory, which houses one of the computers.



With only two objects, you have what is in essence a fire-control problem which, while not simple, is difficult only in the classical sense. That is to say, it calls for a straightforward solution based on mathematics. As such, it is similar in kind, if not in degree, to the problem faced by antiaircraft batteries in World War II.

The solution, based on the trigonometry of moving objects, calls for making one curved path (that of the interceptor or missile) meet another curved path (that of the enemy object). Once the target has been identified, and its location, speed and flight path determined, it's simply a matter of guiding the defensive weapon to it.

In the case of an interceptor, directions are designed to bring the plane close enough to the target to pick it up on its own radar screen, after which the autopilot takes over. The autopilot again provides a solution to a mathematical problem, determining the speed and course the aircraft must fly to come within firing range of the object, and when and where its armament must be employed to bring the object down.

Technique Similar for Missiles

In the case of a missile, the technique employed is similar, although the controls needed to do the job are naturally simpler, since there is no necessity to provide for firing rockets or other armament, or to protect a pilot. Consequently, if you were to examine the electronic gear in a Bomarc missile, you'd find it was similar to that in an F-102, but considerably less complicated. In this instance, of course, the missile's flight path is made to intercept that of the enemy object.

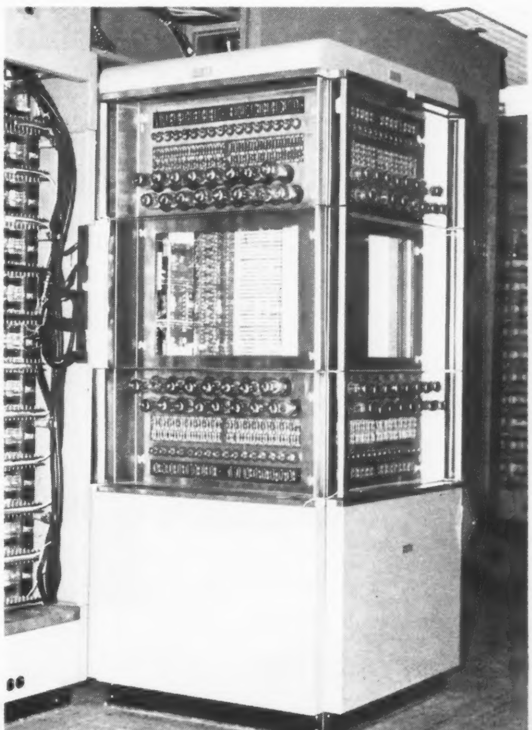
Thus problems involving only two objects are all of the same general variety, and the techniques for solving them, while more sophisticated than those used in the past, are basically the same.

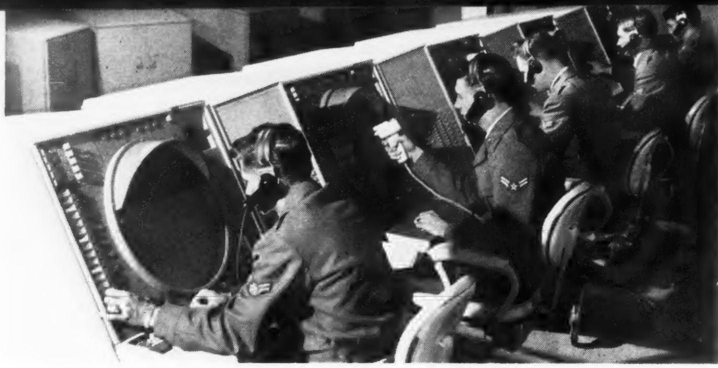
The problem is still that of chasing a pig, even if, in this instance, the pig is moving in three directions and at speeds up to 1200 mph. Obviously, some sort of fire control system is a must to help you catch the pig, but it's not too difficult a job when you have only one pig.

However, it begins to get a little more sticky when you have two pigs, and can't decide which one to go after. In such instances, fire control systems tend to grow confused, with the result that an interceptor sometimes will fire its rockets between two enemy objects, or a missile will carefully make its way between two different targets.

The problem really becomes complicated, how-

FSQ-7 memory stall differentiates and stores inputs at high speed.





Machines do most of the work, but not all. Here Air Force personnel man scopes in the Air Surveillance Room.

ever, when it involves a multitude of enemy objects which form a random and constantly changing pattern of blips on a radar screen and are indistinguishable from your own interceptors or missiles. When you reach this point, how do you manage to assign at least one interceptor or missile to *each* enemy object without shooting down your own weapons?

The answer, of course, lies in SAGE, which has the ability to convert, by electronic means, a complex situation involving, let's say, 100 enemy objects and an equal number of defensive interceptors or missiles, into a number of simple situations, in which interceptors or missiles are assigned to each specific target.

The central problem with the SAGE system, and with all such systems, is the development of a mechanical memory which performs this function—a memory with a much greater span of attention than that of a man. The SAGE computer, developed jointly by the MIT Lincoln Laboratory and the International Business Machines Corp., and believed to be one of the largest in the world, has this capability.

Hooked into a network of radar stations, it not only keeps track of every blip, but also converts complex situations into single, separate situations.

The computer digests all the information received from this radar network and translates it into a composite picture of the over-all air situation. It shows this situation as it is developing and provides the basis for tactical decisions. It also calculates automatically the most effective means of utilizing defense weapons and guides these weapons to their individual targets. And, as the battle moves from the area it serves, it transfers its information to the computer in the adjacent area.

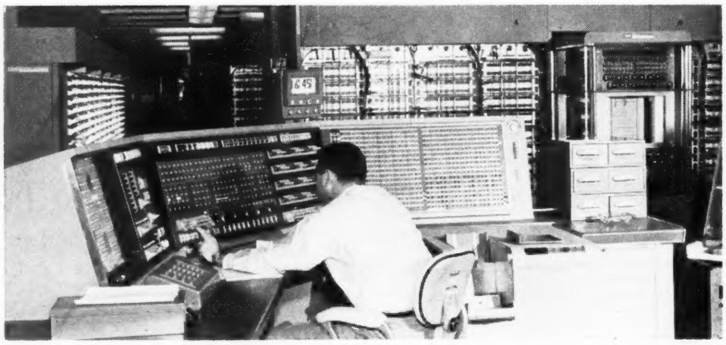
System Gives Over-all Picture

The computer recommends; it does not give orders. The actual decisions are made by human beings—the Identification Officer, the Weapons Assigner, the Intercept Director. These are straightforward decisions, since the computer indicates which defensive weapons are available, where they are located, how they can best be employed and how long it will take each weapon to reach each target.

Now let's take a closer look at exactly how the SAGE system would operate in the event of an enemy air attack.

Let's say five enemy bombers enter the area included in a SAGE detection net. These are immediately picked up on radar screens within the net. This raw information is fed into the computer, and within a matter of moments, the computer plots the course, speed and altitude of the planes, and indicates to the Identification Officer that they cannot be identified as friendly.

On the basis of this (CONTINUED ON PAGE 122)



Maintenance consoles of this kind assure high reliability for the SAGE computer.

ICBM inertial guidance

Here's the story behind development of the "brain" for our largest missiles, a project calling for mass-produced but extremely accurate and reliable components capable of operating in a space environment

By Ernest A. Goetz

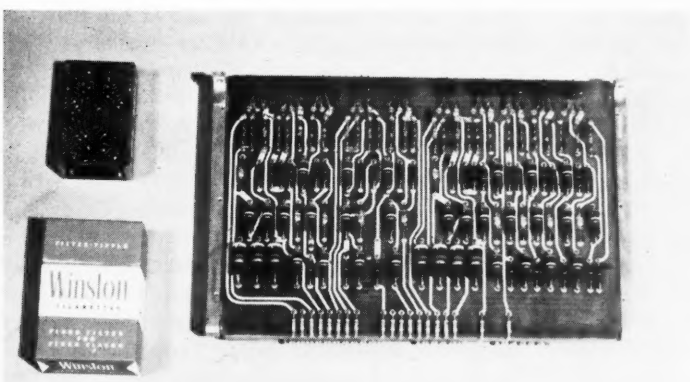
ARMA DIVISION, AMERICAN BOSCH ARMA CORP., GARDEN CITY, N.Y.

THE REALIZATION of ocean-spanning ICBM's, which in the near future will become a part of SAC's arsenal for the defense of the free world, is centered around the creation of a small electronic brain that senses its motion and guides it unfailingly to hostile targets. The development of this brain—the guidance system—small as it is, represents one of the largest expenditures of effort in the development of our ICBM's. Of the 300,000 parts required, a substantial portion are employed in the guidance function.

Technologically, it has demanded the achievement of less weight, greater range, greater accuracy, higher reliability and a capacity to endure greater environmental stress than any guidance system of its kind used in missiles today. Managerially, it has called for interpreting the requirements of the Air Force, integrating the efforts of hundreds of engineers, technical workers and subcontractors, and coordinating with associate contractors to render a system tailored to this need.

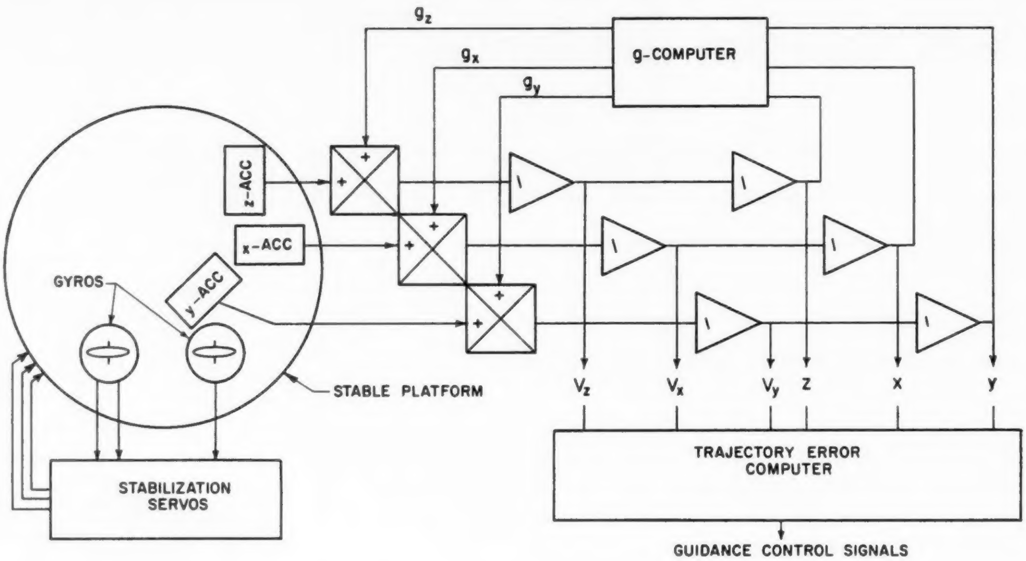
The purpose of this article is to review briefly some of the more interesting technological and managerial highlights of this program.

Ernest A. Goetz, now chief engineer of Arma Div., has been with Arma since 1941, holding down a number of positions in the company's Guidance and Research and Development Departments. He has played a major role in many of Arma's military projects, including the operational B-52 defensive system, the inertial guidance system being developed for the Air Force ICBM program, defense systems for AF long-range bombers, automatic gun-laying systems for main and antiaircraft batteries, Navy navigation systems, Army fire control and navigation systems, pro- and anti-submarine warfare systems, aircraft navigation systems and precision automatic controls for atomic power installations. As chief engineer, he has full responsibility for administration of all engineering programs, which include research, design and development of gyroscopics, computers and control systems for guided missiles and fire-control systems.



Miniaturization in action. Circuit assembly on right, a transistorized digital computer circuit board using conventional high-density packaging, contains 125 parts, weighs 11 oz. Assembly on left has same function but weighs only 1.5 oz.

HOW ICBM INERTIAL GUIDANCE SYSTEM WORKS



In spite of the fact that ballistic missiles draw heavily on the experience obtained from the aircraft and missiles which predate them, they are fundamentally different. Guided missiles were born very early in the history of aircraft development, but it has been only in the last decade that any effort has been expended toward the development of intercontinental strategic missiles.

The earliest effort in this direction represented a mere extension of a vast effort already under way to automatize and simplify the functions of the crew in manned aircraft. In fact, the first efforts merely remoted the crew to a nearby aircraft. The result of this trend was simply an unmanned bomber, subject to most of the limitations that its manned predecessor had encountered. The guidance system had to yield its best results deep in enemy territory, where it was subject to the degradation of enemy interference, long periods of extrapolative estimation, and where it was readily susceptible to enemy counterattack.

These obvious limitations to the pilotless bomber have led the missile engineer to seek new configurations of propulsion, guidance and airframe for the strategic weapons which are not limited by their generic relationship to manned aircraft. One outgrowth of this policy has turned back the pages of military history to one of the most primitive weapons of man—the ballistic weapon.

Ballistic weapons are distinguished by the fact that their target is established at the initiation of flight. From there on, they glide unpowered to the target. During a preliminary phase, thrust is applied to give the missile the velocity necessary to carry it to the target. For example, when a cannon fires a shell, the shell is accelerated in and directed by the barrel. After it leaves the muzzle, it glides ballistically and unpowered to the target.

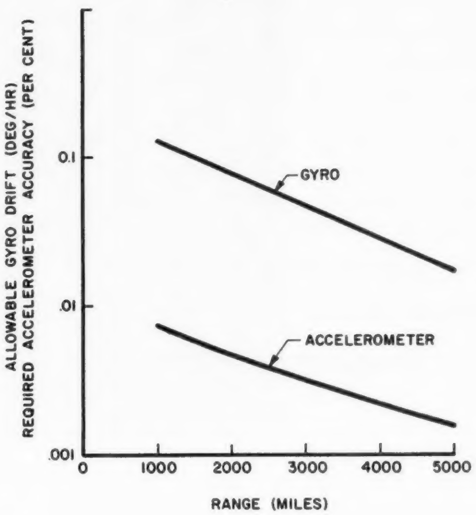
The similarity to the ICBM ends here. The ICBM must attain speeds that are so high they could never be attained in the short span of a gun barrel but must continue to accelerate far out into space. A guidance system must now be used to replace the gun barrel and control the velocity and position of the missile at the end of the powered phase so that it is on a ballistic trajectory which carries it to the target.

Inertial Guidance Is Simplest Method

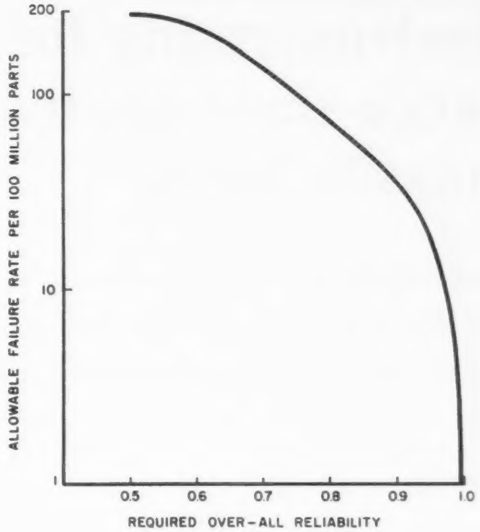
The simplest method of accomplishing this is with an inertial guidance system. This system will sense the inertial reaction to the thrusts applied to the missile, and from them continuously compute its position and velocity. The guidance computer then so controls the missile during the guidance phase that the velocity and position coordinates at the termination of thrust are appropriate for ballistic fall to the target.

One possible limitation of the initiation type of guidance is its dependence upon the predictability

ACCURACY REQUIREMENTS FOR GUIDANCE SYSTEM GYROS AND ACCELEROMETERS



RELIABILITY: HIGH LEVEL OF SYSTEM PERFORMANCE DEMANDS HIGH RELIABILITY OF INDIVIDUAL COMPONENTS



of thrusts that act on the missile after the termination of powered flight. Fortunately for the ICBM's, the major part of their trajectory is far above the atmosphere, free from the unpredictable variations of weather. Needless to say, if required, the inertial system could control and provide the small corrections involved in the process of re-entry with terminal phase guidance.

In contrast to the unmanned bomber type of missile, the ICBM takes full advantage of its freedom from the environmental constraints imposed by human inhabitants, undergoes high accelerations, encounters the severe environmental conditions of outer space. The new configuration pays off, however, in that the decisions of the guidance system are made in the initial stages of the flight, well within the confines of friendly territory, protected from the degradation of enemy interference and long-duration extrapolation.

How does this inertial guidance system work? Three accelerometers measure the vehicle's thrust acceleration, as shown in the schematic drawing on page 46. All mount on a platform held angularly rigid in inertial space by gyroscopically referenced servos. This "stable table" keeps the accelerometers oriented in space along spatially fixed orthogonal coordinate directions. Each accelerometer measures thrust along one of these three coordinates. Outputs of the accelerometers are integrated once to give velocity and a second time to give position.

However, thrust forces are not the only ones acting on the vehicle. There's also gravity. It must be measured and applied to correct the acceleration velocity and position computations. Unfortunately, the thrust accelerometers cannot measure it. Since the gravity vector term depends upon position, the output of the position computer is fed to a gravity computer which determines the gravity component at each position. The gravity term is then used to compensate the measured thrust accelerations. To guide the missile to the target, the inertial computer must be supplemented by a ballistic computer. The ballistic computer controls the engine thrust so that at cutoff the missile will have the appropriate velocity to fall ballistically to the target.

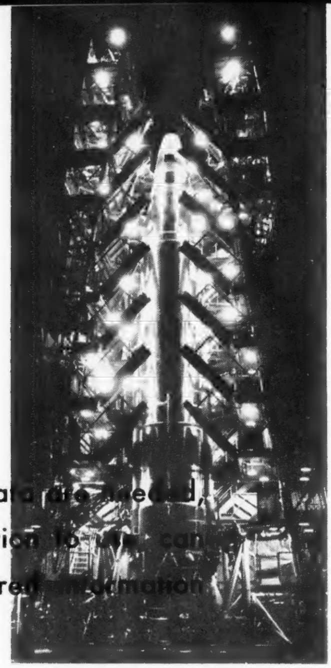
Development of Sensing Components

Position accuracy in a ballistic system depends almost entirely on the performance of the sensing components, especially accelerometers and gyros, and upon the distance that the missile must fly. The drawing at top left of this page shows the accuracy requirements per 1000 ft of error for the most critical components as a function of range.

The development of the sensors for the ICBM represents one of the major technological achievements in the guidance program. These components must be mass-produced and capable of withstanding the environments en- (CONTINUED ON PAGE 126)

Part One

Instrumenting for large-scale captive missile tests



Defining the task to be performed and determining what data are needed, what measurements to make and what type of instrumentation to use can assure tests that run on schedule and produce the required information

By R. A. Ackley

CONVAIR-ASTRONAUTICS,
A DIVISION OF GENERAL DYNAMICS CORP., SAN DIEGO, CALIF.

Robert A. Ackley received his B.S. in physics from Carnegie Tech in 1934 and for the next two years was a staff member of the school's Metals Research Laboratory, working primarily in research instrumentation. This was followed by a year as chief engineer for Gaertner Scientific Corp. and 10 years at Republic Flow Meters. For the past nine years he has been associated with Convair in instrumentation and testing, holding such positions as chief of flight test instrumentation and chief of engineering laboratory testing. In addition to being associated with all recent aircraft testing, he was active in testing of the MX774, Lark and Terrier, and is at present technical staff assistant to the assistant chief engineer—field test, Convair-Astronautics. In this capacity, he has played an active role in field testing of the Atlas ICBM.

INSTRUMENTING for a series of large captive missile tests is similar to the development of a weapon system. The whole *process* must be examined. What are the objectives? What are our capabilities? What time-scale and in what strength must we attack? What degree of kill will be adequate? What back-up and flexibility is required? What support? The time-cycle as well as the content of the process is important.

Without some consideration of the details that define the task, a particular solution loses much of its meaning. Therefore, it would seem advisable to turn first to task definition, and then to a discussion of the solution. The latter will be covered in this article from the standpoint of management and control, of such tests, with technical aspects to be discussed in a subsequent article.

It should be stressed that any plan based on task definition must not be followed blindly. Trouble areas may well require special treatment not in the plan. The data producing system must be flexible enough to follow changes in test plans that result from testing itself. One might say we have a closed loop system in which one of the components, the missile, has some random behavior. If the loop is to be kept closed and under control, the other elements of the system must be flexible and fast acting.

The statement of the task may be divided into three categories, as follows:

1. *Contractual and/or Project Policies:* Two major effects are noted here. First, test missiles are assembled on a production line with tool planning and "released" drawings, including test instrumentation. This expedites the program by supplying missiles in the quantities required and simultaneously develops production methods and tooling. Compared with aircraft, the number of test missiles required is large because of their relatively short operational life. This policy requires extensive early planning of tests and instrumentation to permit design and procurement; rigid control of

design changes because of their disruptive effect on the test program; and special effort to maintain instrumentation flexibility.

Second, the missiles are the property of the customer and subject to his inspection. Any changes must be documented and procedures and test plans approved. The effects of this are not necessarily a hindrance and can be of benefit if planning and procedures are adequate.

2. *Economic Considerations:* As in most practical problems what is required is an economic balance between value received (quantity, quality, when) and value expended (schedule time, manpower, facilities).

Since a single test is of relatively short duration, with actual firing in the order of minutes and final checkout the order of a day, and preparations for a test relatively long (the order of weeks to accomplish and check out changes), it is desirable to reduce preparation time. This requires careful control of changes, minimum instrumentation and efficient check-out procedures. The other prime factor is that of data processing time. To permit preparations for the next test, the data from the last test must be at least partially analyzed. To speed up the process, we have "quick-look," as well as "analysis," data. This affects both instrumentation and data processing.

"Quick-look" data are defined as those data which will determine whether the objectives of the test have been accomplished. In most cases, the objectives of a test are to make certain measurements under prescribed conditions. If the conditions did exist and the measurements were made, the test objectives were accomplished and the systems evaluated. If we attempt to go beyond this, careful judgment is required.

Changes Govern Action To Be Taken

Suppose "analysis" of the data shows that one or more systems failed to perform adequately and further testing is necessary *after some design change.* Here the magnitude of the design change and the urgency of the situation govern the action to be taken. Further "laboratory" testing may be indicated, or scheduled elsewhere at a later date. These decisions are better made by the designer on the basis of "analysis" data rather than on "quick look," although urgency of analysis may well be indicated by "quick look."

3. *Test Objectives:* Rather than consider the whole test program and the place of captive testing in it, let us consider what functions the captive test can economically perform, and those that had best be performed elsewhere.

First, however, a few general remarks on testing are in order. In testing we are generally trying to find out if a change must (CONTINUED ON PAGE 82)

TYPICAL MEASUREMENTS FOR STATIC MISSILE TEST

Type of Measurement	Early Planning Missile	Early Planning GSE	Early Actual Missile	Early Actual GSE	Later Planning Missile	Later Planning GSE
Acceleration						
Rotation (Speed)	2		2		3	
Current	8		9		2	
Displacement	16	2	4	7	2	
Power	6		7		3	
Force	6	12		1		1
Optical		6				
Vibration	150	35	38		5	
Pressure	78	23	51	12	39	2
Frequency	15		10	1	4	
Flow Rate & Angle	5	8	14	4	8	
Strain	26	6		4		
Temperature	50	31	23	3	14	
Voltage	70	15	62	6	45	4
Time	2		2		3	
Position (Seq.)	4	44	7	73	15	81
Sub-Total	478	142	229	111	143	88
Total	620		340		231	

GSE-Ground Support Equipment

Note: These are measurement capabilities, not necessarily to be used simultaneously.

ARS instrumentation and guidance committee

Its new head previews plans for the future, aimed at making ARS the same sort of authority in this area as it is today in the field of propulsion

By Lawrence S. Brown

FORD INSTRUMENT CO., DIVISION OF SPERRY RAND CORP., LONG ISLAND CITY, N.Y.

CHAIRMAN, ARS INSTRUMENTATION AND GUIDANCE COMMITTEE

COMMITTEE CHAIRMAN

Lawrence S. Brown, recently appointed Chairman of the ARS Instrumentation and Guidance Committee, has had almost 25 years of experience in this field. A graduate of the U. S. Naval Academy, he joined Ford Instrument Co. in 1934 after two years of fleet duty, serving as test and field engineer on naval fire control equipment until 1940, when he was assigned to design engineering. In 1953 he joined Bulova Research and Development Laboratories as contract manager, later serving as sales manager. He rejoined Ford in 1954 as project engineer for Redstone guidance and control work on the staff of the president. In 1956, he was named manager of Ford's newly formed Missile Development Division, the position he holds today.

THE PURPOSE of an organization such as ours is to serve as a catalytic agent, accelerating those reactions that tend to be mutually useful to individual members and their general field of interest. Without such usefulness, an organization of this type is of no worth.

The AMERICAN ROCKET SOCIETY embraces a broad range of technologies associated in a common interest. The purpose of its technical committees is to stimulate such reactions within the various fields of interest, and to coordinate the effects to the best advantage of the members and of the field in which they are working.

The ARS Instrumentation and Guidance Committee plans to fulfill its purpose—as will, perforce, the other technical committees—by various means of communication. The most obvious means of communication is through papers presented at national meetings and published in the Society's magazines. By improving the quantity and quality of such technical communications, we are hopeful that ARS can be established as the same sort of authority for guidance and instrumentation of missiles and space vehicles as it now is in the propulsion field.

Today's guidance and instrumentation people are descendants of the instrument and fire-control organizations of the 1920's and 1930's (who could be counted on the fingers of two hands), and who were at the time considered the lunatic fringe of the military technologies, in much the same fashion as were the rocket and space-flight characters. It is significant, however, that—lunatics though they might have been—they did not undertake to design or build the ships they were navigating, the guns they were controlling or the airplanes they were directing. In the main, this has continued to be the practice of these people and their organizations.

It is this devotion of capabilities and resources to their own demanding field of work over the past 20 years that has resulted in the broad base of instrumentation skills now available to our country in these uneasy times.

One characteristic is common to today's weapon systems and tomorrow's space-travel systems. The brains, the senses, the entire nervous networks—that is, the guidance, instrumentation and control

functions—so permeate these systems as to become truly basic to the system concept itself. It becomes increasingly evident that the application of the single system-manager policy will be made with fuller recognition of this fact and that, as a logical consequence, full system responsibility is likely in the future to be more generally assigned to those responsible for the intelligence of the system.

In view of this consideration, and recognizing that most instrumentation and guidance people are already deeply involved in systems work, this committee plans to stress the communications relative to total system problems and techniques. This will be done without overlooking the importance of continued technical advances of subsystems and components.

Lack of a desirably high level of reliability in today's weapons systems is a serious deterrent to obtaining the efficiency required for national security. Such a deficiency in tomorrow's space systems may prove to be a tremendous roadblock. The I&G Committee plans to assist the membership in accenting the truism that reliability may be improved by good workmanship and proved by testing, but can be generated only by proper design engineering. If the latter—for space travel requirements—means reverting to drastically simplified techniques, this must be recognized and pursued.

There is another urgently needed task to which this committee plans to address itself—that of establishing a common language to be applied to characteristics of components, subsystems and systems. One approach would be the framing of a list of unequivocal questions, the answers to which (yes, no or numerical) could serve individually or collectively to determine comparative figures of merit. In military applications, many of the answers will be security-classified. However, the questions need not be. Paradoxically, it is believed that about the same number of questions—say, 100—would serve to cover components (an amplifier, a gyro), subsystems (a stabilizer, an actuator-control) or systems (a Thor, a Jupiter).

Committee to Act as Focal Point

In this area, the Society can perform, both for its own members and for the government, an invaluable service which has not been done properly by other technical and quasi-technical organizations. Subcommittees will be formed to initiate this work, and suggestions from the membership as to how the task can best be accomplished are herewith solicited.

We of the instrumentation and guidance calling are relatively new as a recognizable segment of the councils of the American Rocket Society. This is as it should be from a historical standpoint, since the contribution of our gimmicks would have been pretty academic prior to the magnificent strides made by our flamethrowing brethren. It is because of this chronological circumstance that our responsibilities within the Society are now more clearly highlighted.

The Instrumentation and Guidance Committee plans to act as a focal point for Society communications in our specific technical area. By taking the positive step of directing to the members of this committee suggestions as to papers for meetings, articles for publication and organization of our activities, ARS members in these fields can assure that we attain our goal of mutual usefulness.

THE COMMITTEE

Walter Wrigley
MIT
Vice-Chairman

Theodore Buchhold
General Electric Co.

Herbert Friedman
Naval Research Lab.

Myron D. Lockwood
Sperry Gyroscope Co.

Max Lowy
Ramo-Wooldridge Corp.

Charles J. Mundo
Arma Div.

R. J. Parks
Jet Propulsion Lab.

Robert E. Roberson
Autonetics Div. of NAA

E. King Stodola
Reeves Instrument

William C. Strang
Convair

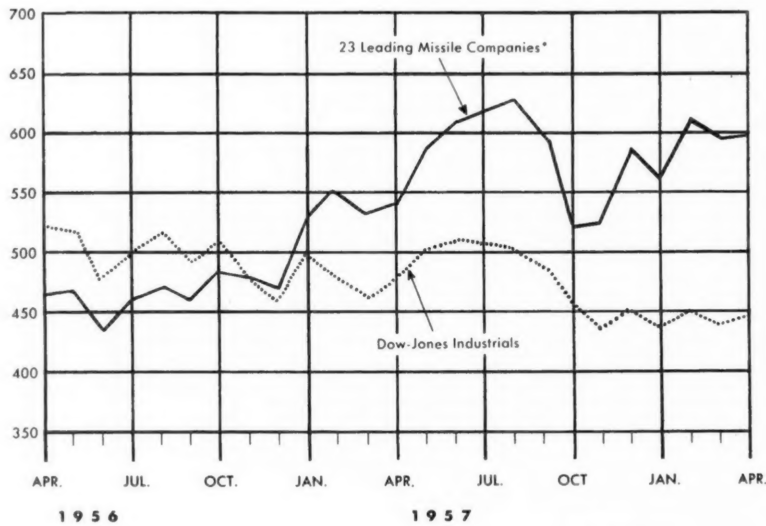
W. H. Thatcher
Bell Telephone Labs.

missile market

Financial news of the rocket and guided missile industry

BY ROBERT H. KENMORE

THE MARKET AT A GLANCE



*Index compiled June, 1955

	April 1958	March 1958	% Change	April 1957	% Change
Dow-Jones Industrials	449	440	+2.0	478	−6.1
Missile Index	596	593	+0.5	543	+9.8

1957 Reports

Company	Sales (Million $)	Earnings Per Share	Change in Earnings from 1956
General Precision	185.1	$3.03	+85%
Thiokol	30.9	1.41	+48%
Chance Vought	237.3	5.65	+48%
Ryan*	76.1	4.02	+44%
General Dynamics	1562.5	4.80	+32%
Boeing	1596.5	5.49	+19%
Aerojet	161.9	0.88†	+11%
American Bosch	134.3	2.67	+10%
Lockheed	868.3	5.52	+ 8%
General Tire	421.2	2.12	+ 4%
Douglas‡	1091.4	8.28	− 8%
American Potash	42.8	2.37	− 8%
Thompson Products	368.6	4.20	− 9%
Martin	423.9	3.38	− 9%
Bell Aircraft	202.3	1.62	−27%

* Fiscal Year ending Oct. 31.
† Adjusted for 10-for-1 split.
‡ Fiscal Year ending Nov. 30.

MARCH, like the previous month, was again marked by narrow movements and no clear trend. In view of the preponderance of bearish news, however, even this narrow movement was much stronger than investors had any right to expect. On a daily basis, the cross-currents in the market give an even clearer indication of constructive hope. On any one day, while the number of issues declining was likely to be much higher than the number of advances, new highs consistently outweighed new lows. This again points up the fact that although the investor can no longer "buy the market," profit opportunities, through careful selection, still exist.

The missile index ended the month virtually unchanged. However, within this framework, while no single issue declined by as much as 5 per cent, four stocks managed to rise in excess of 10 per cent—American Bosch Arma, Raytheon, Marquardt and Reaction Motors.

The definitive lesson to be learned from this type of market activity is that individual corporate developments are being given much more attention than general economic or industry news.

Nevertheless, the major single prop under market psychology continues to be the long-term specter of inflation. The prospect of a peacetime deficit which is likely to exceed $10 billion, following closely upon the heels of a January budget message promising a $500 million surplus, is both a frightening and a sobering phenomenon.

Investors have lived with inflation for a long time, and the experience of succeeding generations has taught them that money doesn't maintain its full value for any extended length of time. Cash (savings) has been a notoriously poor long-term investment. Sometimes, however, the inroads of inflation are imperceptible over a brief span of years. *Deflation* may actually triumph during these short intervals. It is then that investors are tempted to forget the lessons they have been taught, even though the opportunities for successful long-term investments in common stocks are much greater during these same periods.

(CONTINUED ON PAGE 76)

ARS news

Attendance of 850 Marks ASME-ARS Dallas Meeting

MORE THAN 850 members and guests turned out for the highly successful ASME-ARS Aviation Conference in Dallas in mid-March, with a special lecture on Explorer I by Wernher von Braun of the Army Ballistic Missile Agency and an ARS panel on Lunar Colonization drawing the biggest crowds.

ARS and ASME members attending the meeting had their choice of a total of 23 technical sessions at which more than 70 papers were presented. Featured speakers at the three luncheons held in the course of the meeting were Gen. Thomas D. White, Air Force Chief of Staff; Rear Adm. Rawson Bennett, Chief of Naval Research; and Lt. Gen. S. E. Anderson, ARDC Commander. Richard E. Horner, Assistant Secretary of the Air Force for Research and Development, delivered the main address at the banquet.

Von Braun Lauds Vanguard

Dr. von Braun's technical paper drew an audience of almost 1300 people, including more than 300 local students. He began by paying tribute to the Navy for its successful launching of a miniature Vanguard satellite a few days earlier, noting that the Vanguard launching vehicle was considerably more sophisticated than the Explorer vehicle and that development of a very complicated new vehicle of this type in a two-year period was something that had never been achieved before.

Explorer Details Revealed

A number of hitherto unreleased details concerning the Explorer were given in the course of the paper. Dr. von Braun revealed that the Hydyne fuel (March ASTRONAUTICS, page 5) developed by Rocketdyne for use in the launching permitted a substantial increase in first-stage thrust and burning time. Thrust was boosted from 75,000 to 83,000 lb and burning time from 117 to 150 sec, although part of this increase came from the fact that larger propellant tanks were used.

Of particular interest was the ABMA Development Chief's report on temperatures recorded by the satellite. Skin temperatures on the nose ran from 270 to 340 K, while internal temperatures near the low-power transmitter ranged from 100 to 120 F. External temperatures were governed by whether or not the satellite was in direct sunlight, and Dr. von Braun indicated a need for scheduling future firings so that satellites would not be exposed to direct sunlight for long periods while in orbit.

Lunar Colonization panel, moderated by Lt. Col. David G. Simons, AF Missile Development Center, and including such members as astronomer Clyde Tombaugh and human factors specialists Arnold Small of Convair, Eugene Konecci of Douglas-Tulsa and Irwin Cooper of Rand Corp., drew an attendance of almost 400. Technical sessions on nuclear propulsion, drones, high-energy fuels, space flight, instrumentation and aerodynamic propulsion also attracted large audiences.

Space research was the main topic of all the featured speakers. In his banquet address, Secretary Horner outlined some of the problems involved in research programs, pointing out the difference between mass production of missiles and individual projects calling for only two or three vehicles. He urged sympathetic understanding of such problems in order to permit a forward-looking, continuous program.

Research Discussed

Adm. Bennett warned of the dangers inherent in duplication of research, and pointed up the need for better abstracting and classification of the abundance of material that is available so that engineers and scientists working in a particular area can quickly learn what has been and is being done in their own fields.

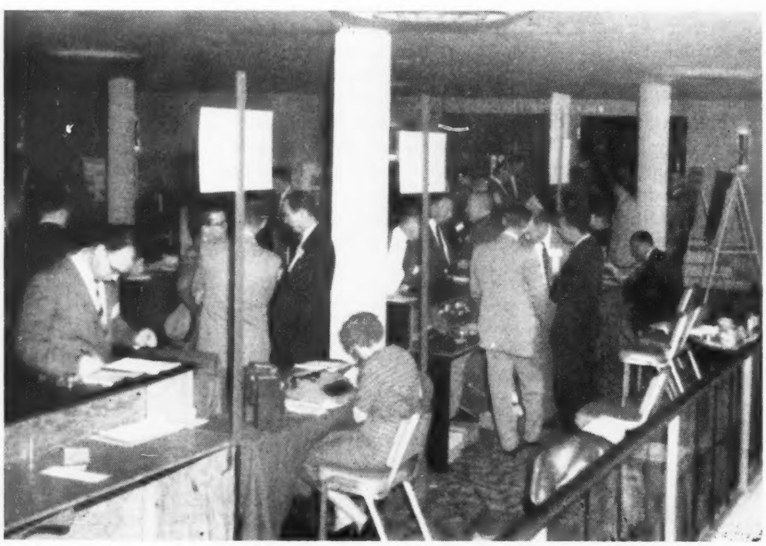
Gen. White plumped for man in the conquest of space, noting that his judgment and skills will always be needed for maximum effectiveness. Development of rocket engines with thrusts of a million pounds or more, better fuels, improved structures and greater reliability were all vital, he added, not only for space vehicles, but also for tomorrow's weapon systems.

Research was also discussed by Gen. Anderson. However, he suggested that development engineering, and applying what is immediately available to the problem at hand, may be even more important in finding the answers to the problem of getting man into space.

The three days of technical sessions were followed by a day devoted to field trips to different missile and aircraft companies in the Dallas area. These also attracted a large attendance.

Local sections of both ARS and ASME did an outstanding job of directing traffic, setting up the technical sessions and field trips and generally pitching in to make the meeting an outstanding success.

—Irwin Hersey



Registration desks were busy throughout the meeting, as more than 850 ARS and ASME members and guests turned out.


At left, J. E. Jonsson, Texas Instruments president, listens closely to banquet address by AF Assistant Secretary Richard E. Horner. At right, ARS President George P. Sutton, ARS Arrangements Committee Chairman George Craig of Convair-Dallas, Wernher von Braun and Austin N. Stanton, Varo Mfg. Co., also lend an ear.

Quick Tour of Dallas Meeting

Rear Adm. Rawson E. Bennett makes a point at press conference at the meeting.

Maj. Gen. C. F. Born of Texas Instruments, general co-chairman of the conference, introduces speaker at welcoming luncheon.

Ross Jordan of Chance Vought says a few words after presenting Wernher von Braun with Texas White Hat.

Arnold Small of Convair answers a question from the audience during the Lunar Colonization Panel as panel member Eugene Konecci of Douglas-Tulsa and moderator David G. Simons check their notes.

J. E. Jonsson, president of Texas Instruments, toastmaster par excellence, at banquet.

DuBridge, Metcalf, Bradbury, Clark to Address L. A. Meeting

Lee DuBridge, president of the California Institute of Technology, will be the banquet speaker at the ARS Semi-Annual Meeting to be held June 9-12, 1958 at the Hotel Statler in Los Angeles, announces Howard S. Seifert, program chairman.

George Metcalf, general manager of General Electric's Missile and Ordnance Systems Dept.; Norris Bradbury, director of the Los Alamos Scientific Laboratory; and Rear Adm. John E. Clark, deputy director of the Advanced Research Projects Agency, will be luncheon speakers.

A 13-session program, including two classified sessions, sponsored by the Air Force Ballistic Missile Div., has been arranged by Dr. Seifert and the ARS Technical Committees, plus the first Western Regional Student Conference and a final-day program which offers registrants the opportunity of choosing from among five attractive field trips.

Responsible for arrangements for the meeting is the host Southern California Section, under G. Daniel Brewer of Ramo-Wooldridge Corp., president. Charles A. Knight also of R-W, is general arrangements chairman.

The complete program, including preprint numbers, is as follows:

Monday, June 9

9:30 a.m.

WESTERN REGIONAL STUDENT CONFERENCE

Chairman: Andrew F. Charwat, University of California, Los Angeles, Calif.

Tutorial Panel on "State of the Art in Rockets and Missiles"

Panel Members: George Sutton, Rocketdyne, Canoga Park, Calif.
John Shafer, Jet Propulsion Laboratory, Pasadena, Calif.
Edward Zukowski, Jet Propulsion Laboratory, Pasadena, Calif.
Samuel Herrick, Department of Astronomy, University of California, Los Angeles, Calif.

9:30 a.m.

MANAGING EXPERIMENTAL ENGINEERING PROJECTS

Chairman: Mortimer Rosenbaum, Convair-Astronautics, San Diego, Calif.

✦ Systems Management for Most Rapid Missile Development, R. F. Mettler, Space Technology Laboratories, Los Angeles, Calif. (611–58)
✦ Transition from Prototype to Production, S. K. Hoffman, Rocketdyne, Canoga Park, Calif. (612–58)
✦ Evolution of New Requirements for Missiles, Ronald Smelt, Lockheed Missile Systems Div., Sunnyvale, Calif. (613–58)
✦ Setting Up a Missile Test Base, W. W. Withee, Convair-Astronautics, San Diego, Calif. (614–58)

9:30 a.m.

TEST INSTRUMENTATION

Chairman: Herbert Friedman, Naval Research Laboratory, Washington, D. C.
Vice Chairman: William Strang, Convair, Pomona, Calif.

✦ Rocket Instrumentation Techniques Utilizing Radioactive Tracers, David E. Shonerd, Era Engineering, Inc., Santa Monica, Calif. (615–58)
✦ Evaluation of Pressure Transducers, Frequency Response, C. R. Tallman, Aerojet-General Corp., Azusa, Calif. (616–58)
✦ A Ten-Band Spectrum Analyzer for Combustion Stability Studies, R. F. Stott, Jet Propulsion Laboratory, Pasadena, Calif. (617–58)
✦ Future Optical Range Instrumentation, E. Stern and D. S. Webber, Space Technology Laboratories, Los Angeles, Calif. (618–58)
✦ Vibration Measurements and Their Meaning, R. R. Giedt, Rocketdyne, Canoga Park, Calif. (619–58)

12:00 noon

LUNCHEON

Speaker: George Metcalf, General Manager, Missile and Ordnance Systems Dept., General Electric Co., Philadelphia, Pa.

2:30 p.m.

WESTERN REGIONAL STUDENT CONFERENCE

Student Paper Presentations

2:30 p.m.

PHYSICS OF FLUIDS

Chairman: Martin Summerfield, Princeton University, Princeton, N. J.

✦ Performance of a Premixed Gaseous Hydrogen-Oxygen Propellant Rocket Engine, Rudolph Edse and Loren E. Bollinger, Ohio State University, Columbus, Ohio. (620–58)
✦ Combustion of a Gas Injected into a Hypersonic Boundary Layer, George W. Sutton, General Electric Co., Philadelphia, Pa. (621–58)
✦ Magnetohydrodynamics and Aerodynamic Heating, Rudolph Meyer, Space Technology Laboratories, Los Angeles, Calif. (623–58)
✦ Thrust Optimization of a Nuclear Rocket of Variable Specific Impulse, H. R. Lawrence, C. J. Wang and G. W. Anthony, Space Technology Laboratories, Los Angeles, Calif. (651–58)

Tuesday, June 10

9:30 a.m.

HANDLING AND TESTING LIQUID ROCKET AND RAMJET ENGINES

Chairman: B. F. Beckelman, Boeing Airplane Co., Seattle, Wash.
Vice Chairman: Dwane M. Crowl, Marquardt Aircraft Co., Van Nuys, Calif.

✦ Large Liquid Propellant Rocket Test Operations, Daniel M. Tenenbaum, Aerojet-General Corp., Sacramento, Calif. (624–58)
✦ The Influence of Jet Properties on Uncooled Deflecting Surfaces, Albert N. Baxter Jr., Space Technology Laboratories, Los Angeles, Calif. (625–58)
✦ Evaluation by Flight Test of the Talos Ramjet, W. E. Worley, Bendix Products Division, Mishawaka, Ind. (626–58)
✦ Ramjet Operational Experience from Development Flight Testing, H. R. Dettwyler, Marquardt Aircraft Co., Van Nuys, Calif. (627–58)

9:30 a.m.

OPERATIONS RESEARCH APPLIED TO EXPERIMENTAL ENGINEERING

Chairman: Peter Weiser, Ramo-Wooldridge Corp., Los Angeles, California.

✦ Systems Approach to Experimental Engineering, Alex Boldyroff, Rand Corp.,

George Metcalf

Lee DuBridge

Rear Adm. John E. Clark

Santa Monica, Calif. (628–58)
✦ Scheduling Tests and Forecasting Hardware for Research and Development Programs for Liquid Propellant Rocket Engines, I. Nagin, Aerojet-General Corp., Sacramento, Calif. (629–58)
✦ Predicting Liquid Oxygen Requirements for Multiple Research and Development Programs, J. L. Beebe, Rocketdyne, Canoga Park, Calif. (630–58)
✦ Optimum Number of Launchers for Operational Missile Squadrons, M. Smith, The Martin Co., Denver, Colo. (631–58)
✦ Reliability Achievement and Demonstration in a Development Program, H. R. Lawrence and W. H. Amster, Space Technology Laboratories, Los Angeles, Calif. (632–58)

12:00 noon

LUNCHEON

Speaker: Norris Bradbury, Director, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

2:00 p.m.

WHAT IGY HAS TOLD US ABOUT SPACE

Chairman: W. H. Pickering, Jet Propulsion Laboratory, Pasadena, Calif.
✦ Rockoon Experiments and Explorer Cosmic Ray Experiments, J. A. Van Allen, State University of Iowa, Iowa City, Ia. (633–58)
✦ Explorer Temperature Measurements, A. R. Hibbs, Jet Propulsion Laboratory, Pasadena, Calif. (634–58)
✦ 47 Research Rockets at Fort Churchill, N. W. Spencer, University of Michigan, Ann Arbor, Mich. (635–58)
✦ Solar Flare Program and Ionizing Radiation in the Night Sky, Herbert Friedman, Naval Research Laboratory, Washington, D.C. (636–58)
✦ Meteorological Rocket Data Soundings in the Arctic, W. G. Stroud, U. S. Army Signal Engineering Laboratory, Belmar, N.J. (637–58)

2:00 p.m.

BIO-SATELLITES

Chairman: Irwin Cooper, Rand Corp., Santa Monica, Calif.
✦ Decompression Events in Bio-Satellites, Eugene B. Konecci, Douglas Aircraft Co., Tulsa, Okla. (638–58)
✦ Criteria for the Selection and Training of a Bio-Satellite Crew, D. W. Conover, J. Aiken, Arnold Small, Convair, San Diego, Calif. (639–58)
✦ A Program for Space Biological Experiments, George W. Hoover, Office of Naval Research, Washington, D.C. (640–58)
✦ New Chamber Techniques for Space Research, Siegfried Hansen, Litton Industries, Beverly Hills, Calif. (641–58)

7:00 p.m.

BANQUET

Speaker: Lee DuBridge, President, California Institute of Technology, Pasadena, Calif.

Wednesday, June 11

9:30 a.m.

MISSILE LAUNCHING OPERATIONS (CONFIDENTIAL)

Sponsored by Air Force Ballistic Missile Division

Chairman: Herbert L. Karsch, Aeronutronic Systems, Inc., Glendale, Calif.

Hotel Statler in Los Angeles, scene of the ARS Semi-Annual Meeting June 9–12.

✦ Redstone Launching, T. T. Paul Jr., Army Ballistic Missile Agency, Huntsville, Ala.
✦ Thor Launching, J. L. Bromberg, Douglas Aircraft Co., Santa Monica, Calif.
✦ Regulus Launching, Fred W. Randall, Chance-Vought Aircraft, Pt. Mugu, Calif.
✦ Titan Launching, Robert Bowles, Glenn L. Martin Co., Denver, Colo.

9:30 a.m.

GUIDANCE OF SPACE VEHICLES

Chairman: Robert E. Roberson, Autonetics, Downey, Calif.
✦ Attitude Control for a Space Vehicle, Walter E. Haeussermann, Guidance & Control Laboratory, ABMA, Huntsville, Ala. (642–58)
✦ Optical Determination of Orientation and Position Near a Planet, Robert E. Roberson, Autonetics, Downey, Calif. (643–58)
✦ Vibration-Induced Drift of Gyroscopic Instruments, R. M. Stewart, Space Technology Laboratories, Los Angeles, Calif. (644–58)
✦ A Method of Determining Steering Programs for Low Thrust Interplanetary Vehicles, E. Rodriguez, Autonetics, Downey, Calif. (645–58)

12:00 noon

LUNCHEON

Speaker: Rear Admiral John E. Clark, Deputy Director, Advanced Research Projects Agency, Washington, D. C.

2:00 p.m.

ROCKET ENGINE SYSTEMS (CONFIDENTIAL)

Sponsored by Air Force Ballistic Missile Division

Chairman: G. Daniel Brewer, Space Technology Laboratories, Los Angeles, California.
✦ Development of the Thor IRBM Propulsion System, R. R. Morin and R. Healy, Rocketdyne, Canoga Park, Calif.
✦ The Explorer Rocket System, H. J. Stewart, Jet Propulsion Laboratory, Pasadena, Calif.
✦ The Polaris Propulsion System, W. R. Kirchner, Aerojet-General Corp., Azusa, Calif.
✦ Future Trends of Solid Engine Development, William Pennington, Space Tech-

Astronautical Exposition Exhibitors List Grows

A large segment of the nation's space flight wares will be on display before the 2000 ARS members and guests expected to attend the special Astronautical Exposition to be held in conjunction with the Semi-Annual Meeting at the Statler. So far, the list of exhibitors include:

Douglas Aircraft Co.
American Potash & Chemical Corp.
Western Gear Corp.
Norris Thermador Corp.
North American Aviation, Inc. Missile Development Div.
Thiokol Chemical Corp.
Solar Aircraft Corp.
Aerojet-General Corp.
Walter Kidde Co.
Callery Chemical Co.
Sundstrand Turbo Div.
Chance Vought Aircraft
Northrop Aircraft
Bell Aircraft Corp.
Food Machinery & Chemical Corp.
Ramo - Wooldridge - Thompson Products
General Electric Co.
Westinghouse Electric Corp.
Aeronutronics Systems

on the calendar

1958	
May 1, 8, 15, 22, 29	Gas Dynamics Colloquium, Technological Institute, Northwestern U., Evanston, Ill.
May 5–7	Fourth National Instrumentation Flight Test Symposium of ISA, Park Sheraton Hotel, NYC.
May 6–8	Western Joint Computer Conference, Ambassador Hotel, Los Angeles, Calif.
May 19–22	17th Annual Conference of the Society of Aeronautical Weight Engineers, Belmont Plaza Hotel, New York, N.Y.
June 2–4	**National Telemetering Conference under auspices of ARS, IAS, AIEE, ISA, Lord Baltimore Hotel, Baltimore, Md.**
June 9–12	**ARS Semi-Annual Meeting, Hotel Statler, Los Angeles, Calif.**
June 16–18	Second National Convention on Military Electronics, sponsored by IRE, Sheraton Park Hotel, Washington, D.C.
June 19–21	**Heat Transfer and Fluid Mechanics Institute Meeting, University of California, Berkeley.**
June 23–July 3	Special Summer Program in Random Vibration, MIT, Cambridge, Mass.
June 25–27	1958 Air Transportation Conference, sponsored by AIEE, Statler Hotel, Buffalo, N.Y.
July 8–11	IAS National Summer Meeting, Ambassador Hotel, Los Angeles, Calif.
Aug. 13–21	10th Assembly of the International Astronomical Union at Moscow.
Aug. 25–30	**Ninth Annual Congress of International Astronautical Federation, Amsterdam, The Netherlands.**
Sept. 1–6	1958 Farnborough Flying Display and Exhibition, Farnborough, England.
Sept. 3–5	1958 Cryogenic Engineering Conference, MIT, Cambridge, Mass.
Sept. 8–13	First International Congress of Aeronautical Sciences, sponsored by IAS, Madrid, Spain.
Sept. 15–18	**ARS Meeting, Hotel Statler, Detroit, Mich.**
Sept. 22–24	IRE National Symposium on Telemetering, the American Hotel, Bal Harbour, Miami Beach, Fla.
Sept. 24–25	National Electronics Conference, sponsored by IRE, AIEE, EIA, Hotel Sherman, Chicago.
Nov. 10–13	AF School of Aviation Medicine-Southwest Research Institute Space Flight Symposium, San Antonia, Tex.
Nov. 17–21	**ARS 13th Annual Meeting, Hotel Statler, New York, N.Y.**

nology Laboratories, Los Angeles, Calif.
✦ Advanced Liquid Propulsion Systems, H. Ellis, Aerojet-General Corp., Azusa, Calif.

2:30 p.m.

FLIGHT DYNAMICS OF SPACE VEHICLES

Chairman: Krafft A. Ehricke, Convair-Astronautics, San Diego, Calif.
✦ Earth-Moon Trajectories, Louis Gold, Massachusetts Institute of Technology, Cambridge, Mass. (646–58)
✦ Lunar Satellites, Krafft A. Ehricke, Convair-Astronautics, San Diego, Calif. (647–58)
✦ Interplanetary Trajectories Under Low-Thrust Radial Acceleration, Jack Copeland, Autonetics, Downey, Calif. (648–58)
✦ Satellite Tracking, Eberhardt Rechtin, Jet Propulsion Laboratory, Pasadena, Calif. (649–58)
✦ Recovery from a Satellite Orbit, Richard Hoglund and J. Thale, Cook Research Laboratories, Morton Grove, Ill. (650–58)

Thursday, June 12

8:30 a.m.

FIELD TRIPS

1. Aerojet-General Corp., Azusa, Calif. (including Aerobee and Vanguard areas).
2. Consolidated Western Steel Div., U. S. Steel Corp., Maywood, Calif. (including production of Nike-Hercules launchers, rocket engine cases)
Jet Propulsion Laboratory, Pasadena, Calif. (including Explorer areas).
3. Northrop Aircraft, Inc., Hawthorne, Calif. (including Snark areas)
Rocketdyne Div. of North American Aviation, Inc., Canoga Park, Calif. (including firings at Santa Susana)

Nominations Invited For ARS Awards

Kurt R. Stehling, Chairman of the ARS Awards Committee, invites nominations for 1958 awards and fellow memberships. Nominations may be made by any ARS member, but must be submitted through the local ARS Section. Deadline date for nominations is Aug. 15.

The awards are as follows:

Robert H. Goddard Memorial Award, for contributions to the development of liquid rockets.

C. N. Hickman Award, for contributions to solid rocket development.

James H. Wyld Memorial Award, for development of applications of rocket power.

ARS Astronautics Award, for contributions to astronautics.

G. Edward Pendray Award, for contributions to the literature of rocketry, jet propulsion and astronautics.

Fellow memberships are awarded for eminence and important contributions in these fields.

Missile Production Papers Sought for Detroit Meeting

Charles W. Williams of Chrysler Missile Operations, who is heading up a session on missile manufacturing set for the ARS Fall Meeting in Detroit September 15–18, is seeking suggestions for subjects and authors for the session, including, wherever possible, abstracts of material which may be available.

Suggestions as to papers which are available, as well as topics of interest to ARS members, may be sent to Mr. Williams at Chrysler Missile Operations, P.O. Box 2628, Detroit 31, Mich.

Regional Space Technology Meeting to be Held Aug. 5-6

The San Diego sections of the American Rocket Society and the Institute of the Aeronautical Sciences are jointly sponsoring a regional meeting on space technology in San Diego Aug. 5–6. Attendance will be limited to members of both societies in sections as far north as San Francisco and as far east as Denver.

Abstracts of proposed papers for the meeting should be sent immediately to the general chairman, Richard Linnell, at the following address:

Dr. Richard Linnell
Institute of the Aeronautical Sciences
3380 N. Harbor Drive
San Diego 1, Calif.

Charles L. Critchfield, Convair's director of scientific research, is honorary chairman of the meeting. Tentative plans call for Jim Dempsey, Convair-Astronautics Div. manager, to host a tour of the division's new plant during the two-day program. Depending upon security developments, a tour of the Atlas production line and test facilities may also be included.

William H. Dorrance, president of the ARS San Diego Section, and Donald Germeraad, chairman of the IAS San Diego Section, extend invitations to other regional section members to participate in the program. The program will include classified and unclassified papers in propulsion, structures, trajectories, upper atmosphere research, entry and re-entry, earth satellites, human factors, interplanetary flight, and motivations and incentives.

Papers presented will be considered for publication in technical journals of the two societies by the appropriate editorial review committees.

Program Set for National Telemetering Conference

The 1958 National Telemetering Conference, to be held June 2–4 at the Lord Baltimore Hotel, Baltimore, Md., will highlight manufacturers' exhibits, three field trips, 16 technical sessions, including one classified session, a number of prominent guest speakers, a ladies' program and entertainment. The conference is co-sponsored by ARS, AIEE, ISA and IAS, and is supported by the National Academy of Sciences and the military.

Sessions will be devoted to systems, IGY activities, data processing, components and equipment, astronomy, cosmic ray studies and rocketry. The classified session will be held on Thursday morning, June 5. A number of foreign papers will be presented, including some Russian papers.

On Monday morning, June 2, technical sessions will deal with industrial telemetering, pickups and mobile telemetry, to be followed by luncheon and an address by Gen. Earle Cook, Director of Army Signal Engineering Laboratory, Fort Monmouth, N.J., on "Telemetering Requirements of the U.S. Army." Afternoon sessions will cover industrial telemetering, medical telemetering and mobile airborne telemetry.

On Tuesday morning, technical papers will be read on IGY telemetry and data processing. The luncheon speaker and topic will be Adm. Gordon Caswell, (USN Ret.), "Problems of International Frequency Allocation." IGY telemetry and data processing will be the topics that afternoon. At the banquet that evening, G. M. Thynell of The Johns Hopkins University Applied Physics Laboratory, and NTC chairman, will deliver a welcoming address. Adm. Blinn Van Mater, (USN Ret.) will speak on "Telemetering in the IGY."

Wednesday morning sessions will cover transistors, mobile systems and mobile ground telemetry. During the afternoon, papers will be presented on systems problems and mobile systems.

Further details on the conference may be obtained from E. T. Loane, C. & P. Telephone Co. of Maryland, 320 St. Paul Place, Baltimore 2, Md.

Mementos for Ex-Officers

At the ARS National Board of Directors meeting in Dallas, the board unanimously approved a plan to present small tokens of appreciation to outgoing national presidents, directors and technical committee chairmen of the Society, as well as to outgoing section presidents.

Five Companies Become ARS Corporate Members

Five companies have joined the growing roster of AMERICAN ROCKET SOCIETY corporate members. The companies, along with their areas of activity and individuals named to represent them in ARS are:

- **Dearborn Machinery Movers, Inc.,** Dearborn, Mich., specializing in launching towers, wind tunnels, test tracks, and missile and aircraft plants. Named to represent the company in ARS activities are: Edward R. Galli, president; Robert F. Thomson, Harold W. Rector and Charles R. Shanks Jr., vice-presidents; and L. S. Campbell, sales manager.

- **Kaiser Metal Products, Inc., Fleetwings Div.,** Bristol, Pa., manufacturer of rocket motor cases, liquid fuel tanks, high-pressure vessels and other missile components. Representing the company in ARS are: S. D. Hackley, vice-president; W. K. Palmer, manager; E. J. Raymond, contracts manager; D. E. Egan, sales manager; and C. G. Cudhea, assistant to the vice-president.

- **B. F. Goodrich Co.,** Akron, Ohio, active in research, development and production of rocket propellants and missiles. Named to represent the company in ARS are: Harold W. Catt, general manager, aviation products; Archie B. Japs, manager, rocket development; Fred T. Marshall, director of government relations; George W. Flanagan, Washington representative; and M. W. Osborne Jr.

- **Research Staff, General Motors Corp.,** Detroit, Mich. Named to represent the company in ARS are: J. M. Campbell, scientific director; N. D. Crane, special assistant to the scientific director; D. H. Loughridge, head, Nuclear Power Engineering Dept.; R. S. Rae, head, Weapons Systems Dept.; and C. R. Russell, consulting engineer.

- **Wyle Laboratories,** El Segundo, Calif., independent testing company active in development, qualification and production testing of aircraft and missile flight and ground control components involving fuels, hydraulics, pneumatics and cryogenics, including high-flow liquid and gaseous oxygen. Representing the company in ARS are: Frank S. Wyle, president; Robert S. Gardner, vice-president and laboratory director; Edward Rubin, assistant to the president; Zvi Schacter, production manager; and John R. Herring, division manager, cryogenics and mechanical testing.

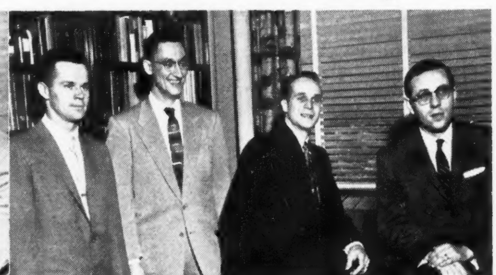
SECTIONS

Alabama: Fritz Mueller, head of the Guidance Control Laboratory, Development Operations Div. of ABMA, was the featured speaker at the March meeting. A pioneer in the development of missile guidance systems, he presented an unclassified talk on the subject to an interested audience.

Central California: Col. Peter J. Schenk, president of the Air Force Assn. and consultant on defense relations to the Defense Evaluation Operation of General Electric Co. in Washington, was the guest speaker at the April meeting. His topic: "A National Defense Program in the Air Atomic Age."

Columbus: The March meeting drew a record turnout of 125 people. Loren Bollinger, newly elected president of the section, took over the reins at the meeting. Guest speaker for the evening was Capt. Albert Momm, who gave an engaging talk on the subject of Navy missiles. Capt. Momm showed a number of interesting slides demonstrating the striking power of various Navy weapons and discussed development of various missile projects. At the conclusion of the talk, he showed a film depicting the firing of several Navy missiles. The meeting wound up with a lively question-and-answer period.

Snapped at the March Columbus Section Meeting



At left, Capt. Albert Momm, guest speaker, and new section president Loren Bollinger. In photo at right are (left to right) James Harp, president Bollinger, Dean L. Pendleton and David Haswell.

Dayton: About 50 people turned out for the organization meeting of the new Dayton group, which is expected to receive its charter in the near future. William J. Cushing of Burroughs Corp. and Capt. Rod W. Clarke of the Directorate of Systems Management, ARDC, Wright Air Development Center, have been the motivating force behind organization of the group.

At the first meeting, Gordon Eckstrand of the Psychology Branch, Aero Medical Laboratory, WADC, presented an interesting talk on the problems involved in sending a man to the moon.

A nominations committee has already begun selection of a slate of candidates for section offices on whom members will ballot by mail prior to the next meeting.

Holloman: Norris E. Bradbury, director of the AEC's Los Alamos Scientific Laboratories since 1945, was the guest speaker at the February meeting. Other guests at the meeting were Col. Mitsuo Kawamata, head of the Medical Service of the Japanese Air Force, and James H. Klein, head of aviation medicine for Stanley Aviation Co., Denver.

In his address, Dr. Bradbury traced the history of the Los Alamos establishment, and discussed a few of the general technical problems connected with its work. He noted that temperatures and pressures involved in fusion and fission explosions are in a range which he referred to as a "never-never land" of physics.

As regards the place of nuclear energy in future commercial and industrial power, he made it quite clear that nuclear power will not be cheap. In fact, Dr. Bradbury stated that only when gasoline reaches perhaps $1 a gallon would nuclear power be interesting.

He added that he wanted to make nothing more than an educated guess as to when we may control nuclear power from fusion. His educated guess is, at the earliest, 20 years from now.

He concluded with the opinion that the USSR is a small number of years behind us in nuclear engineering competence, but that we certainly haven't any reason for complacency.

A special series of lectures on problems related to man's conquest of interplanetary space has been scheduled in the months to come. Knox Millsaps, president of the section and Chief Scientist, AF Missile Development Center, Holloman AFB, has extended an invitation to the public to attend the talks.

Fritz Zwicky, professor of astrophysics at Cal Tech, staff astronomer

at the Mt. Wilson and Palomar Observatories and chief research consultant for Aerojet, was the guest speaker at the group's April meeting, discussing the man-made meteors he helped develop and which were recently accelerated to escape velocity and hurled into interplanetary space.

Other speakers in the series will be George Sutton, ARS national president and chief of preliminary design, Rocketdyne, who will address the May 13 meeting; Hans von Ohain, inventor of the turbojet and designer of the first jet engine, at the June 3 meeting; Samuel Herrick of UCLA, at the July 8 meeting; and Hubertus F. Strughold, of the AF School of Aviation Medicine.

—**Lt. Col. H. L. Gephart**

Maryland: Warren W. Berning, Ballistic Research Laboratories, Aberdeen Proving Grounds, was the guest speaker at the March meeting. His topic was "The IGY Rocket Research Program at BRL." The meeting was held at the Proving Grounds and was prefaced by a visit to a display of IGY rockets and instrumentation at the base museum.

Philadelphia: Gerhard Barth-Wehrenalp, of Pennsylvania Salt Mfg. Co.'s Whitemarsh Research Lab, has been elected president of the section for the coming year. Other newly elected officers are: Jack Walton, GE, vice-president; Mrs. Emily R. Gibbs, secretary; and Bill Brown, Texas Co., treasurer. John J. Konikoff of GE heads the program committee, Walton the membership committee and Abe Bernstein of Philco Corp.'s Research Div. the education committee.

Sacramento: On Feb. 24, the Sacramento Section held its annual installation-of-officers banquet at the Coral Reef restaurant. Over 60 members and wives attended this dinner meeting, at which Antoni K. Oppenheim, past president of the Northern California Section, and associate professor of mechanical engineering at the University of California, Berkeley, was guest speaker. Dr. Oppenheim told of the history, aims and future plans of ARS and also discussed his plans to attend, along with Theodore Von Kármán, the Third Colloquium, Combustion & Propulsion Panel, AGARD, NATO, being held during March at Palermo, Sicily.

The new section officers were installed preceding Dr. Oppenheim's most enjoyable talk.

—**George S. James**

Southern California: A discussion of "Design Problems of Large Rockets" by Karel J. Bossart, technical director of Convair-Astronautics and a fellow member of ARS, highlighted the Feb. 27 meeting. In his talk, he declared

Clair M. Beighley, new Sacramento section president accepting gavel from past president Dan M. Tenenbaum.

that, as far as can be seen, none of these technical problems seem insurmountable, and the limit where dead weight becomes so large that missile payload cannot be increased is probably in the range of size of a large ocean liner like the Queen Mary.

However, the limiting factor in missile growth is likely to be economic, rather than technical, he went on, pointing out that it will be reached when it is more costly to accomplish a given mission with one large missile than with two smaller ones.

He felt we are already approaching the ultimate size for missiles having to fly in the atmosphere, but that for vehicles destined to fly in satellite orbits or beyond, very much larger dimensions will be practical.

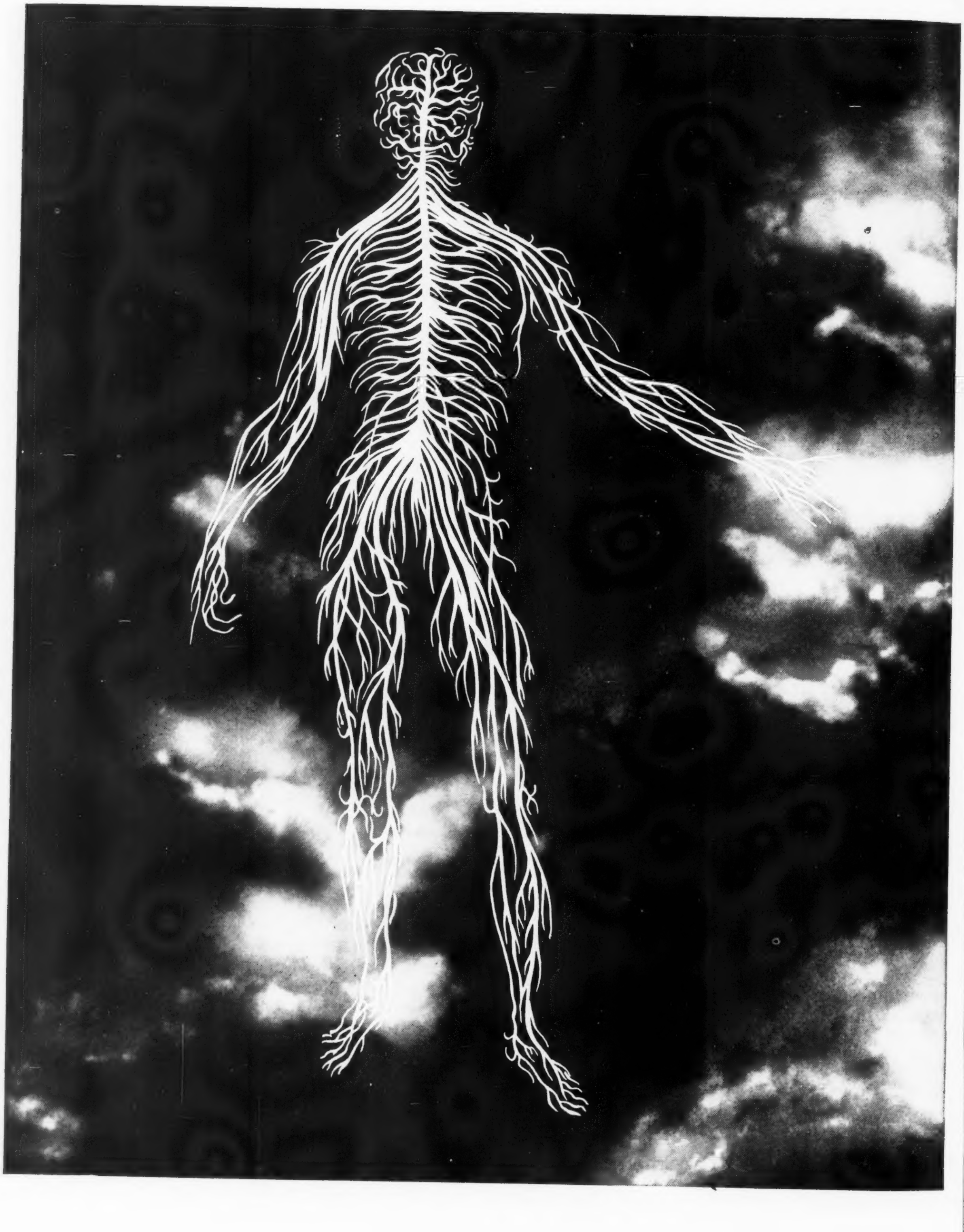
—**Eric Burgess**

Southern Ohio: A joint meeting with the local ASME section devoted to the theme of "Propulsion for Space Flight" brought out a large attendance early in March. Speakers and topics were: Peter Kappus, "Propulsion in the Age of Space Flight"; Spiridon N. Suciu, "Principles of Rocket Propulsion"; F. E. Schultz, "Design of Liquid Propellant Engines"; Thomas Omori, "Solid Propellant Rockets"; and William R. Corliss, "Exotic Propulsion Systems."

ASME president James N. Landis and Ernst Allardt, regional ASME vice-president, were guests at the meeting.

STUDENT CHAPTERS

University of Virginia: Highlight of the March meeting was presentation of the chapter's charter by Dean Roberts, ARS director of public relations, who also delivered a brief talk on the history of the Society. Guest speaker at the meeting was Beaufort Ragland of the Richmond Astronautical Society, whose topic was "Environmental Conditions on the Moon and the Planet Mars."



Radar Development

(CONTINUED FROM PAGE 29)

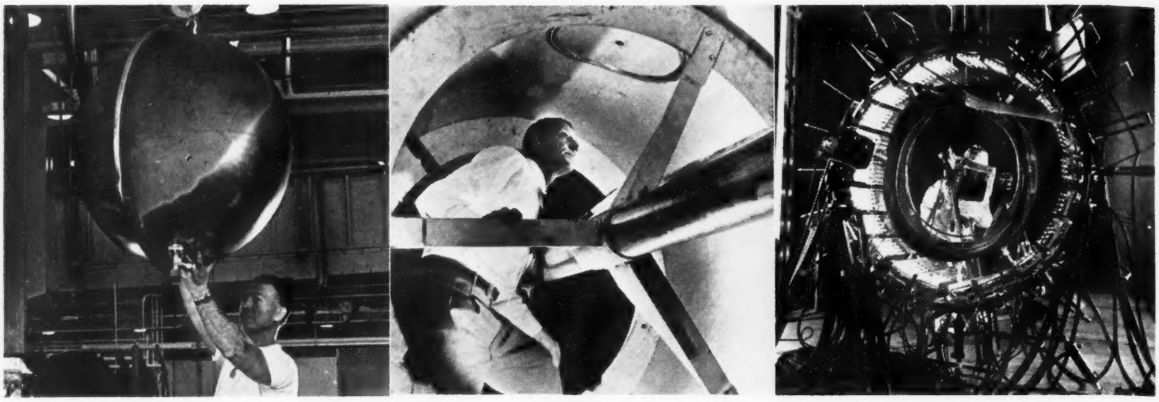
for a given frequency result in a narrower beam with which to scan a given volume of space. Mechanical tolerances become intolerable as the beam-width becomes narrower. The solution is not only to increase antenna size, but also to lower the operating frequency. While the antenna beam-width and transmit-gain may remain unchanged, the larger antenna intercepts more of the received signal to provide an over-all system gain. At the lower frequencies, receiver noise figures are generally lower, and hence more favorable. Higher powered components are easier to build for the lower frequencies. This trek back down the frequency scale has caused antenna and RF component designers to dust off discarded approaches and apply new knowledge learned in their higher frequency interlude.

In the field of antennas, notable advances are being made in scanning devices. Mechanical scanners are being replaced with more sophisticated quasi-electronic or pure electronic scanning devices. Some of these devices scan by means of a frequency shift, others by more subtle means, such as through the use of ferrite phase shifters. One application for electronic scanning is in shipborne use, wherein antennas are stabilized by electronic means, rather than through the use of bulky, mechanical stable-platforms.

Ferrite devices are making an impact in many RF component designs. They seem to violate the law of reciprocity, and any measure of relief, particularly from such stolid dictates as the radar range equation, is welcomed. Ferrite devices, along with other RF component innovations, such as the short-slot hybrid and the strip transmission line, are providing the tools for many novel and exceedingly useful methods for handling RF signals, notably in the field of precision tracking.

Not all modern radar applications require extremely high RF powers. For missile guidance, the accent is on accuracy. Beacon equipment may be carried aboard the missile to receive signals from the ground and return strong replies. Since the return-power is much more than that which would be received from reflections off the missile skin, power requirements are eased considerably. Sufficient power is required only to assure a good signal-to-noise ratio for accurate tracking and a high degree of invulnerability to interfering signals.

The vulnerability of radio-inertial command guidance systems to jam-



Building the X-15: First Photos

Details of X-15 fabrication are shown for first time in these photos. Left, seam-welded fuel tank of stainless steel is inspected. Center, North American technician checks seamless weld in fuselage section. Right, simultaneous heating and cooling of metal ring representing part of fuselage is studied by structures engineer with movie camera.

ming has frequently been exaggerated. These systems employ radio or radar to determine the position and velocity of the missile and to relay commands to direct the missile along a desirable trajectory. They combine the best features of radar and inertial elements. While it is not possible to say categorically that these systems cannot be electronically jammed, as in the case of all-inertial guidance systems, jamming a properly designed radio-inertial guidance system is an exceedingly difficult, uneconomical and undependable mode of defense. It is like saying that automobile tires are susceptible to blowouts—but then who rides on solid rubber tires?

The advantage of radio-inertial guidance is in its extreme precision, its lightweight, low-cost equipment aboard the missile, and, in some applications, for its ability to redirect a missile during flight and, to a degree, to assess the missile's success. The flight computer may remain off the missile for greater over-all system reliability and enhanced accuracy through the use of more sophisticated guidance equations. Gravitational anomalies encountered along the guided portion of the trajectory do not affect accuracy.

Modern tracking radars are of the monopulse type. That is, they derive angle error information on each and every pulse, as contrasted with trackers which look first to one side of a target and then to the other to derive angle error signals by comparing the signal returns received with the beam in these two positions. Monopulse trackers have the advantage of being more accurate, especially in the face of fluctuating signals.

Some monopulse trackers are of the all-amplitude type, with two beams spaced in azimuth and two in elevation, deriving angle information by comparing simultaneously the strengths of signals received by pairs of beams. Other monopulse systems are all-phase, comparing the time of arrival of signals received by pairs of (effectively) spaced antennas.

The most modern are combination phase-amplitude monopulse trackers. These have numerous advantages, such as having a perfect null defining the electrical axis of the antenna, even with imperfect comparators. They are much simpler, both in RF plumbing and signal processing. They lend themselves admirably to circuitry which can be made to nullify automatically gain or phase changes due to circuit unbalance as might result from the replacement of a receiver tube.

Great Advances Made

Tracking antennas and mounts have received considerable attention with the need for ever greater tracking accuracy. Tremendous advances have been made in reducing antenna sidelobes which degrade accuracy due to spurious signals received from ground reflections. Differential temperature effects which distort the antenna have been reduced through the use of reflective paint, sun shields and air-conditioned radomes. "Gear noise," disturbing the smooth movement of the antenna, has been eliminated by eliminating the gears! Instead, single-speed, direct-drive motors are used to turn the antenna. Electronic signals derived from the radar beam itself are used to correct angles taken from the mechanical axis of the antenna mount.

The main drive for a bulky, high-inertia antenna need not keep the electrical axis of the antenna pointing directly at the target at all times. The actual position of the target is derived from both the mechanical position of the mount and the electrical error signals from the radar beam. Tracking radars today are highly precise instruments, comparable to a huge surveyor's theodolite, and are essentially limited only by the effects of radio propagation anomalies.

Even propagation effects are being assaulted through the use of long baseline systems which have a greater "lever arm" with which to triangulate on the received signal so as to give greater angular sensitivity as compared with propagation "noise." But success doesn't come easily. Baselines several hundred feet long must be used to realize appreciable benefits.

In such systems, it is necessary to pass a coherent "timing" signal between two stations on either end of the baseline. Small temperature changes in the transmission path or line over which the timing signal is sent cause timing errors and an apparent angular shift of the direction

ICAS International Forum To Be Held Sept. 8-13

Some 40 scientists representing 18 nations will present technical papers at the First International Congress of the Aeronautical Sciences, to be held under the sponsorship of the Institute of the Aeronautical Sciences Sept. 8–13 in Madrid, Spain, at the Palace Hotel.

to the signal source being tracked. Another problem is one of resolving ambiguous information which results from the use of baselines which are long as compared with the operating wave length.

Much more use is being made in modern radar of the characteristics of radar signals. Information theory has pointed the way toward a better understanding of communication problems in general, providing means for circumventing difficult design problems. We have come to appreciate more fully the characteristics of radar signals that limit the detection and resolution of targets. Much has recently been accomplished in the area of developing wave-forms tailored to specific radar applications, and in processing signals once they are received. Criteria other than the amplitude of the received signals are being used to determine the presence of a bona fide signal.

Doppler Radars More Important

Doppler radars, both pulsed and CW, requiring coherent, extremely stable sources of RF energy, are becoming more prominent and necessary to solve military problems. Radars are making more use of the "color" of radar signals, the fourth dimension, that of Doppler resulting from target motion. Even further dimensions in target signature are being put to use, such as the polarization characteristics of the RF wave. Modern radars "track" in several dimensions at once to enhance signal-to-noise ratios and to distinguish the target from spurious effects.

With high-power radar, even meteors and other galactic noise cause confusion. To keep pace with the trend toward coherent radar systems, high-powered, easily turnable klystrons, traveling wave tubes and voltage-tuned magnetrons are being developed to amplify stable frequency sources.

Earlier limitations of transistors are gradually being overcome. Transistors for operation at more than 100 mc have been developed and marketed, as have transistors of 50 to 100 watts dissipation. Their use is spreading in radar applications from peripheral circuitry, such as digital computers and intermediate connecting and processing circuits, where transistors are operated predominately either in one stable state or another, to the more difficult applications where their advantages in power consumption, size, weight, reliability and long life are being exploited.

Advances in computers and allied data handling, processing and recording techniques have had considerable impact upon radar and associated weapon systems. They make possible more complete, far faster use of data, which, for almost any radar, comes spewing out at an astonishing rate, faster than a human can cope with. Military problems are so complex, in the case of missiles involving speeds of thousands of miles per hour, that the human operator's job must be reduced essentially to one of maintenance, surveillance and a few simple operational choices. Radars, therefore, have become much more automatic. Information is automatically read, stored and operated upon by devices which were unavailable a decade ago.

Devices in this category include storage tubes wihch can be made to remember radar "pictures" and from which the information may be taken at a different rate or in different coordinates than that in which it was transcribed. It includes magnetic tape, magnetic drums, punched paper tape, magnetic core storage devices and a variety of delay lines. It includes tracking circuits which remember a target's characteristics, such as its velocity vector, to perform a track-while-scan function.

It includes a variety of recording devices which are transforming the evaluation and trouble-shooting of radar, permitting higher degrees of reliability to be achieved and making a higher order of complexity practical. It includes a host of sensing or measuring devices such as mechanical shaft-to-digital converters which today read angles rapidly and with accuracies better than one part in one-quarter million. This angular accuracy is equivalent to an angle subtended by an arc a city block in length one-quarter of the way around the world —at ICBM ranges.

Any article on recent developments in radar would be incomplete without some recognition of the immense growth in managerial problems attendant to the development of the large, complex weapon systems required to solve modern military problems. Radars were once essentially systems in themselves. Today, they often are an integral part of a much larger complex—often far-flung weapon systems involving missiles, communication links thousands of miles long, a maze of computers and control links.

Continuous Program Vital

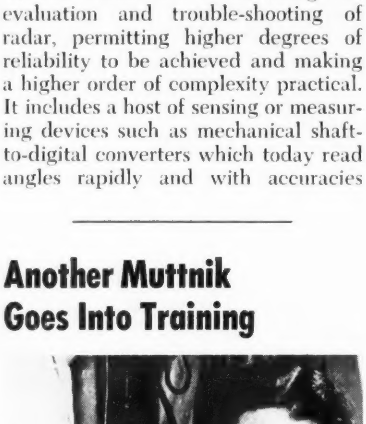
Military necessity requires a short span from system requirements to operationally usable equipment. The result is a vastly greater need for planning and a continuous, uninterrupted program from "cradle-to-grave," wherein the various phases of the development program are accomplished largely in parallel, rather than in series. Model improvement must be planned as an intimate part of the program, phasing in long before tests are complete. Reliability requirements must be recognized from the start of a program, and factored heavily into all phases of development.

Systems engineering takes on broader implications. The system to accomplish the military task must first be synthesized in broad terms, then analyzed to determine how well it should perform its function, although these are nearly inseparable and never-ending elements of a development program. Questionable technical areas must be supported by technique development. With this accomplished, or at least well under way, specific design studies and finally equipment design can begin.

Equipment designs must be integrated, often with weapon system contractors spread throughout the nation. The equipment must be evaluated against equipment specifications and military requirements in programs that require an immense amount of planning and effort. There must be a tight feedback between field evaluation and equipment design. Throughout development, the problem of system utilization must be kept uppermost in mind, including human factors, the means for transportation, maintenance and logistics.

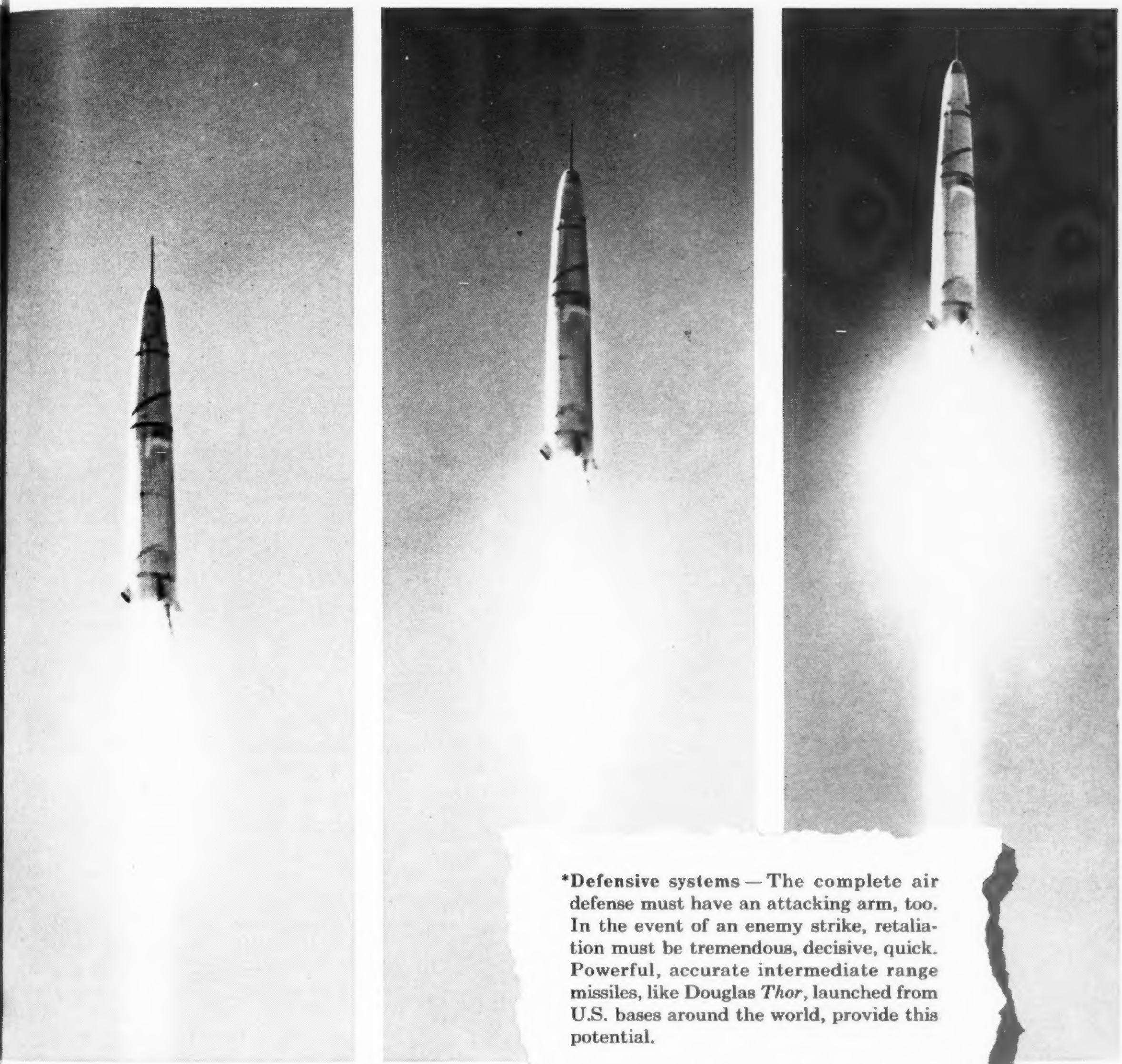
Radar has grown up. It has assumed responsibilities in the defense of our nation for which we can all be proud and thankful.

Another Muttnik Goes Into Training



Soviet physiologist trains Alpha, dog Russians say is destined to be a passenger in new Sputnik now under construction.

white areas show extensive use of magnesium



*Defensive systems — The complete air defense must have an attacking arm, too. In the event of an enemy strike, retaliation must be tremendous, decisive, quick. Powerful, accurate intermediate range missiles, like Douglas *Thor*, launched from U.S. bases around the world, provide this potential.

an strike anywhere in the world from U.S. bases!

ing, launching, training and parts replacement.

Such thoroughness is typical of Douglas where 19,000 missiles of all types have been produced since 1941. In fact, Douglas is the *only* U.S. manufacturer to have developed missiles systems in all categories...air-to-air, air-to-surface, surface-to-air, and surface-to-surface. And Douglas has an accumulation of missile experience unequaled in the U.S.

Depend on

DOUGLAS

First in Missiles

people in the news

APPOINTMENTS

Robert C. Truax, Air Force Ballistic Missile Div., Inglewood, Calif., and immediate past-president of ARS, has been promoted to Captain, date of rank Dec. 1, 1957.

Col. John P. Stapp, ARS vice-president, has been named head of the Air Force Aero Medical Laboratory, Wright Air Development Center, Ohio. **Lt. Col. David G. Simons** succeeds Col. Stapp as Chief, Aero Medical Field Laboratory, Holloman AFB, N. M.

Robert M. Lawrence, assistant treasurer, Reaction Motors, Inc., and ARS treasurer, has assumed the additional posts of assistant secretary, RMI, and director of its Finance Div. **W. G. Lundquist** has been retained as technical consultant and adviser on the Pioneer rocket engine being developed by RMI for the X-15.


Lawrence

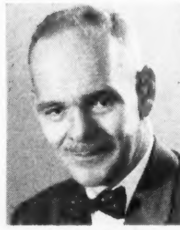

Lundquist

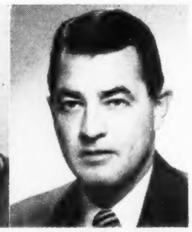

Jorczak


Moore

Joseph S. Jorczak, vice-president, Thiokol Chemical Corp., has been appointed president, National Electronics Laboratories. **Raymond T. Moore,** vice-president, NEL, has been named to the board of directors and also general manager. **Brig. Gen. Clyde K. Rich** becomes assistant to Moore.

Thomas I. Paganelli, manager, Missile Detection Systems Section of General Electric Co.'s Heavy Military Electronic Equipment Dept., will head the project team that will supervise engineering, production and installation of the new super-radar system that will be part of the over-all AF Ballistic Missile Early Warning System.


Hayward


Beauchamp

Brig. Gen. Richard W. Hayward, (USMC-Ret.), has joined Aerojet-General to assist with the planning and design of the Pacific missile range. **Jack M. Beauchamp,** Aerojet's representative in northeastern states and eastern Canada, has been named director of field service.

Aeronutronic Systems, Inc., has promoted former directors **Joseph V. Charyk,** aeronautics, and **Montgomery H. Johnson,** nucleonics and physics labs, to be directors of missile technology and advanced research, respectively.

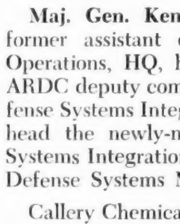
Donald Millenson has joined Hamilton Standard Electronics Dept. as project engineer, missile development.

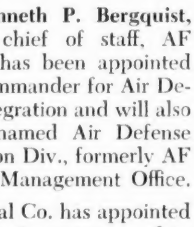
Maj. Gen. Kenneth P. Bergquist, former assistant chief of staff, AF Operations, HQ, has been appointed ARDC deputy commander for Air Defense Systems Integration and will also head the newly-named Air Defense Systems Integration Div., formerly AF Defense Systems Management Office.

Callery Chemical Co. has appointed **J. S. Bardin** production manager of its plants in Muskogee, Okla., and Lawrence, Kan. **G. F. Willard** has been made assistant plant manager, Muskogee.

Herbert R. J. Grosch, former ARS president, has been appointed director of sales services, IBM Data Processing Div. Grosch formerly was application section manager, GE Computer Dept., Phoenix.

Robert M. Bowie, corporate director of research, and **Melvin E. Lowe,** project manager, have been appointed vice-president, Sylvania Research


Grosch


Lowe

Laboratories and manager, Missile Systems Laboratory, Sylvania Electronic Systems, respectively.

John Mason, former senior project engineer, Garret Corp.'s AiResearch Mfg. Div., has been promoted to chief, preliminary design.

Alan M. Glover and **William T. Warrender** have been appointed general manager and general projects manager, respectively, of the newly established RCA Semiconductor and Materials Div. Glover was formerly general manager, RCA Semiconductor Div.; Warrender, general manager, RCA Components Div.

Henry G. Giuliani has joined Stavid Engineering, Inc., where he will work in the weapon systems engineering area.


Giuliani


Funk

Brig. Gen. Ben I. Funk, chief, AF Ballistic Missiles Office and Ballistic Missiles Manager, Air Materiel Command, Inglewood, Calif., has been promoted to Major General.

Siegler Corp.'s Olympic Radio .& Television Div. has realigned its Military Engineering Div. and named **Henry S. Katzenstein** to the new post of director, Research Dept., **Abe Cohen** to be head of military product development and **Ruby Blumkin** to head up military product design.

Sundstrand Turbo Div., Sundstrand Machine Tool Co., has appointed **Harry M. St. John** assistant general manager and **Joseph C. Triolo** to the new post of works manager, Denver plant.

Fred M. Hakenjos, former smokeless powder sales manager, Hercules Powder Co., has been promoted to manager of the newly formed Chemical Propulsion Div. of the Explosives Dept.

T. Ross Welch has been named general manager of Telecomputing Corp.'s Components Div.

Ernest O. Rolle, former technical consultant, Aerophysics Development Corp., and founding president, ARS Central California Section, has estab-

lished a technical consultant service in telecommunications, European engineering developments and inventions in Santa Barbara, Calif.

Harold E. Francis, former assistant chief engineer, Wright Aeronautical Div., has been named senior staff engineer of Chandler-Evans Div. of Pratt & Whitney.

Francis

Dalgleish

John E. Dalgleish, former chief, Fabrication Div., U. S. Flight Propulsion Laboratory, has been named manager, Veet Industries Turbo-Rocket Div. Veet recently acquired the Rocket Div. of Kodiak Corp., Cleveland.

Herbert Harris Jr., former chief engineer of Sperry Gyroscope's Air Armament Div., has been appointed manager of the division.

Johannes G. Schaberg has joined Control Data Corp. as staff engineer, Cedar Engineering Div. Schaberg was formerly manager, General Mills Mechanical Div.'s Inertial Systems Dept. and Laboratory.

Melville D. Bowers has been appointed head of the electronics section, Edison Research Laboratory.

John W. Black has been appointed plant manager, Tucson, Ariz., operations of Hughes Aircraft Co., succeeding the late George Sinclair. **Louis L. Reasor** succeeds Black as assistant plant manager.

Lloyd V. Berkner, president of Associated Universities, Inc., has been elected to Texas Instruments board.

E. M. Baldwin has been named vice-president, general manager and a member of the board of directors, Fairchild Semiconductor Corp. He was formerly manager of product engineering for Hughes Aircraft Co. Products Group, Semiconductor Div.

Electro-Snap Switch & Mfg. Co. has formed a new Missile Components Group with the following officers: **J. P. Barthell,** chief design engineer; **R. Provart,** technical director; **H. F. Ames,** managing director; and **Kacil Brin,** application service director.

Delco Radio Div. of GM has started a special research and development program devoted to missile transistor applications and circuitry. **Frank Jaumot Jr.,** director of semiconductor research and engineering, heads the program, and has appointed **Ralph Brown** manager of the project.

Douglas Aircraft has set up a top level engineering council to be chaired by engineering vice-president **A. E. Raymond.** Other members will be the heads of the company's six major engineering divisions: **E. F. Burton,** Santa Monica; **E. H. Heinemann,** El Segundo; **Elmer P. Wheaton,** Missiles; **C. C. Wood,** Long Beach; **C. E. Strang,** Tulsa; and **R. L. Hoskinson,** Testing. **W. B. Klemperer,** chief, missiles research section, has been appointed staff assistant to chief missiles engineer **E. P. Wheaton. J. M. Tschirgi,** missiles engineer, succeeds Klemperer.

Radiation, Inc., has named **Lawrence Gardenhire** to head its newly formed Astrionics Div., responsible for research and development of instrumentation systems and associated equipment.

HONORS

Charles C. Lauritsen, professor of physics, California Institute of Technology, has been awarded the second annual Captain Robert Dexter Conrad Award by ONR for his outstanding technical and scientific achievements in research and development for the Navy.

The Geophysics Research Directorate, AF Cambridge Research Center, Bedford, Mass., has selected **Rita C. Sagalyn** as Guenter Loeser Memorial Lecturer for 1958, in recognition of her outstanding achievement in meteorological research.

Frederick Pittera, chairman, Consolidated Aerodynamics Corp., has received the highest Air Force civilian award, a Certificate of Appreciation, "in recognition of public services rendered to the AF and reserve, and outstanding cooperation and continuous effort to further the national security of the U. S."

Missile Market

(CONTINUED FROM PAGE 52)

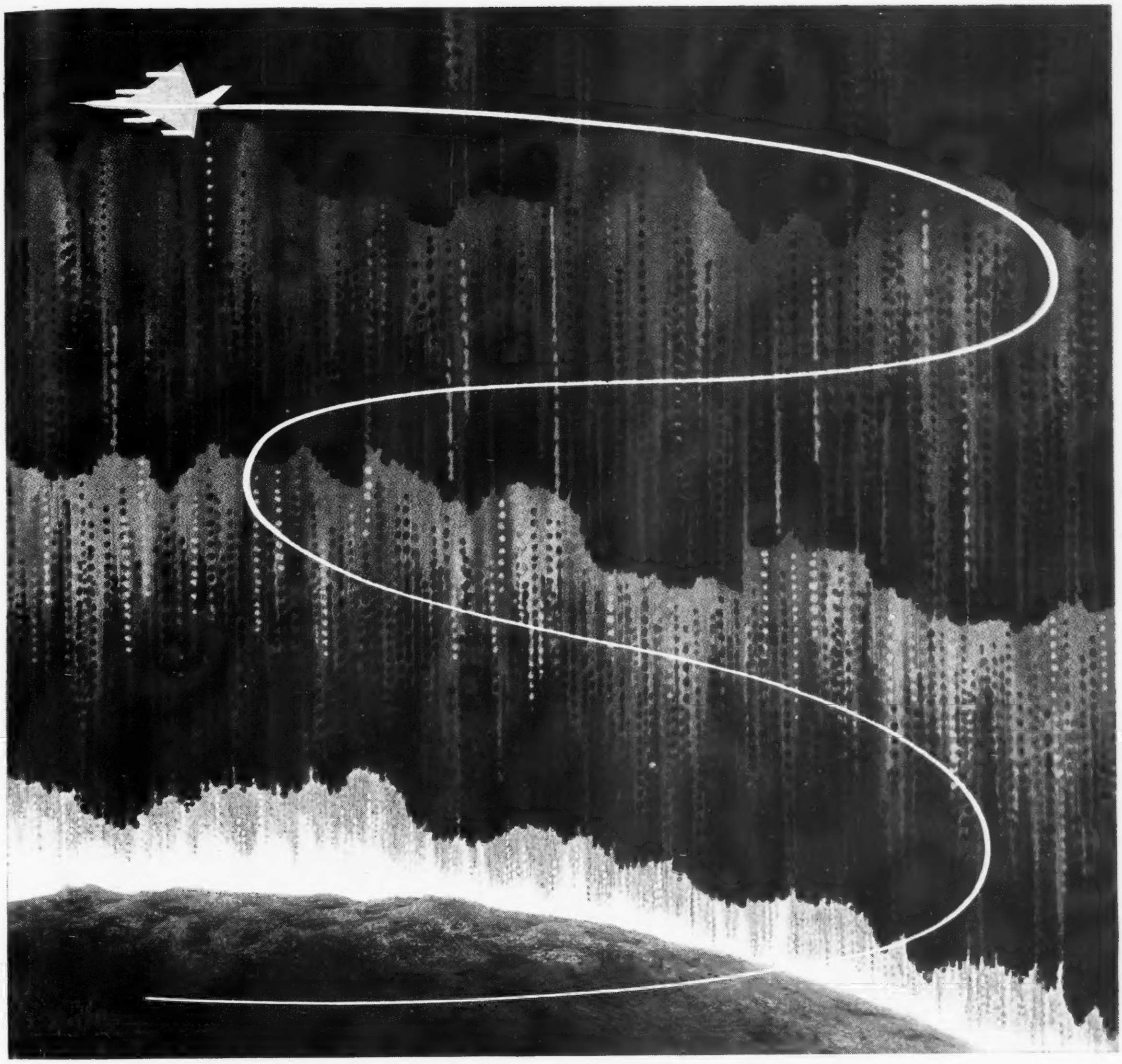
Investors must take a long-range view, just as corporations must plan ahead in terms of years, not months. If one has investible funds, one should not give undue importance to whether this money is invested with the Dow Jones at 450 or at 410, or whether a stock is bought at 32 or at 29. Five years from now, when the purchasing value of the pre-war dollar will be down to 40 cents or less, it will probably make very little difference what you paid for your stocks in 1958. In restrospect, they will look cheap.

Some economists continue to insist that increased defense spending does not have much effect on the economy, since most of it is for missiles which do not require, in relative terms, huge amounts of materials. In light of this, it is interesting to study the effects of a large missile maker's recently announced intention to hire an additional 1000 men for a plant currently employing 7000. It will mean a population increase of 2960 and 1120 more households; personal-income increase of \$5.9 million; a total of \$2.7 million more in bank deposits; a passenger-car increase of 1070; a total employment increase of 1740; a total of \$3.6 million more in retail sales annually; and the establishment of 40 more retail businesses.

It is not hard to estimate what this community's Chamber of Commerce thinks of economists' pronouncements!

Financial Briefs

Northrop Aircraft increases earnings in six months ending January 31 to \$1.82 per share, a 24 per cent rise over the previous year despite a \$10 million drop in sales. Current backlog of \$275 million is 46 per cent missile work . . . *Lockheed's* current backlog of \$1.28 billion (20 per cent below the year-earlier figure) consists of 13 per cent missiles and satellite projects, 44 per cent AF planes, 10 per cent Navy planes, 28 per cent commercial planes and 5 per cent miscellaneous military services . . . *Chance Vought's* year-end backlog at \$670 million. Company expects an additional 24 per cent increase in earnings for 1958 (on top of the 48 per cent increase in 1957) on sales of \$300 million . . . *American Potash* sees 1958 earnings as "something over \$2" . . . *Martin* backlog at \$795 million, 60 per cent for missiles and associated equipment, and expects 1958 results to be "comparable" to those of 1957 . . . *North American Aviation's* sales estimates for the current fiscal year (to Sept. 30) are revised upward to \$800 million, with earnings expected to be between \$14 and \$21 million (vs. \$34 million in previous year). Backlog is at \$585 million . . . *Bendix* expects sales, earnings to fall in current fiscal year . . . *Boeing's* year-end backlog at \$2.5 billion, with 1957 profit margin dropping to 2.39 cents per dollar of sales vs. 3.19 cents the previous year . . . *Ryan's* year-end backlog at \$117 million . . . Some of the most active stocks on the N.Y. Stock Exchange trading in 1957 were North American Aviation (6th most active), Sperry Rand (7th), General Dynamics (8th) and Boeing (9th).



the international scene

BY ANDREW G. HALEY

I HAVE just concluded a long and arduous tour of the principal cities of Europe—a tour undertaken for a number of reasons.

First, it was necessary for me to confer with Prof. J. M. J. Kooy and Netherlands Conference Officials in The Hague concerning arrangements for the Ninth Annual Congress of the International Astronautical Federation, to be held in Amsterdam Aug. 25–30.

Also, a meeting with the Bureau of the International Council of Scientific Unions had been scheduled at The Hague to discuss the cementing of relations between the ICSU and the IAF. I was also desirous of further cementing relations between the IAF and UNESCO.

In addition, it was necessary to coordinate committee activities resulting from action taken at the IAF Barcelona meeting last year. This meant meeting with members of the Cooper Committee, the Committee on Correction and Revision of the IAF Constitution, and the *Astronautica Acta* Committee.

I had also been asked to give a number of lectures on the current legal and economic aspects of astronautics.

And, last but by no means least, many European countries do not as yet have astronautical societies, and extensive preparations had been made by leading scientists in a number of these countries to organize such societies, and my presence had been requested at organization meetings.

° ° °

The first stop on the trip was Dublin, where Prime Minister Eamon de Valera was gracious enough to invite me to a private conference, in the course of which we discussed astronautics for more than 20 minutes. I also had the great pleasure of meeting with several distinguished scientists from Armagh Observatory, Armagh, Northern Ireland; Queens University, Belfast; Trinity College; and National University, Dublin. It was unanimously decided to organize, within the framework of the Irish Astronomical Society, an Astronautics Division, which, for all purposes, would be a coordinate society. We all had the cheering thought that, on this occasion, all of Ireland was united under the aegis of one astronautics group!

My next stop was London, where I had a pleasant conference with Dr. L. R. Shepherd of the British Interplanetary Society, after which I left for Stuttgart. I was met by Dr. Eugen Sänger and we were joined later by Dr. Irene Sänger-Bredt and by a host of old friends in the Deutsche Gesellschaft für Raketentechnik und Raumfahrt, including Dr. Welf Heinrich, Prince of Hanover. That night, the Prince and I lectured at a meeting of the DGRR.

From Stuttgart, I flew to Hanover, and, with the Prince, motored to Loccum for the "Man in Space" colloquium. The three-day visit at the Loccum Academy was indeed a memorable experience. The first evening we heard an excellent lecture by Prof. Hermann Volk of Münster University on "The Position of Man in the Universe." The next morning, Prof. Ernesto Grassi of the University of Munich talked on "Curiosity and Historicality of Man," and the program continued with lectures on "Space Travel, Some Political Aspects," Dr. Sänger; "Space Travel and Conception of Time," Prof. Max Born; "Space Travel and the Public," Baron Karl-Georg von Stackelberg; "The Word at the Beginning and at the End of Time," Dr. Hans Bolewski; "What Are the Upper Limits of State Jurisdiction Over Air Space?," by the Prince; "The Law of the Space Age—Spiritual and Scientific Foundations," by myself; "Biological Problems of Space Travel," Professor Heinz von Diringshofen; "The Spiritual Consequences of the Conquest of Space," Dr. Guenther Anders; and "God, Universe, Earth," Bishop D. Hanns Lilje.

During the general discussion, the group was somewhat shocked by Dr. Born, who sharply criticized those who pursue astronautics on the ground that the only real application of all such effort was warlike in nature. This charge was promply challenged by the Prince, and an exciting debate ensued.

The entire proceedings were summarized and analyzed on the last day of the colloquium by Dr. Lilje, Lutheran Bishop of Hanover, who disposed of controversial issues with complete lucidity, pointing out that the case for world peace through astronautics was a stronger case than failure to tackle this inevitable evolution of civilization because of fear.

° ° °

I then proceeded to Paris, where I spent the week-end with Dr. Theodore von Kármán, who had just arrived from the U.S. Brussels was my next stop. Here, I conferred with Lee V. Gossick and Dr. Henri Janne, Rector of the Brussels University, learning that an Astronautics Society has actually been formed in Belgium.

Leaving Brussels, I moved on to The Hague, where I conferred with Prof. and Mrs. Kooy and Mrs. Volten concerning this year's IAF Congress. That evening, I addressed the combined Societies of Nederlandse Vereniging voor Ruimtevaart and Koninklijke Nederlandse Vereniging voor Luchtvaart.

The next morning I met with the ICSU Bureau. The possibilities of ICSU-IAF cooperation had already been presented to the Bureau by Dr. Lloyd V. Berkner, President of ICSU, and it was decided at the meeting:

1. To set up immediately an *ad hoc* Exploratory ICSU-IAF Committee to examine the possibilities of establishing contact between ICSU and the IAF.
2. That IAF consider the possibility of sponsoring a scientific union, or, alternatively, that the IAF be reorganized.

The Exploratory Committee was nominated as follows: ICSU—H. S. W. Massey (U.K.), Convenor; P. Swings (Belgium); and Fred Whipple (U.S.). IAF—Theodore von Kármán (U.S.), Co-Convenor; Leonid Sedov (U.S.S.R.); and E. Vassy (France).

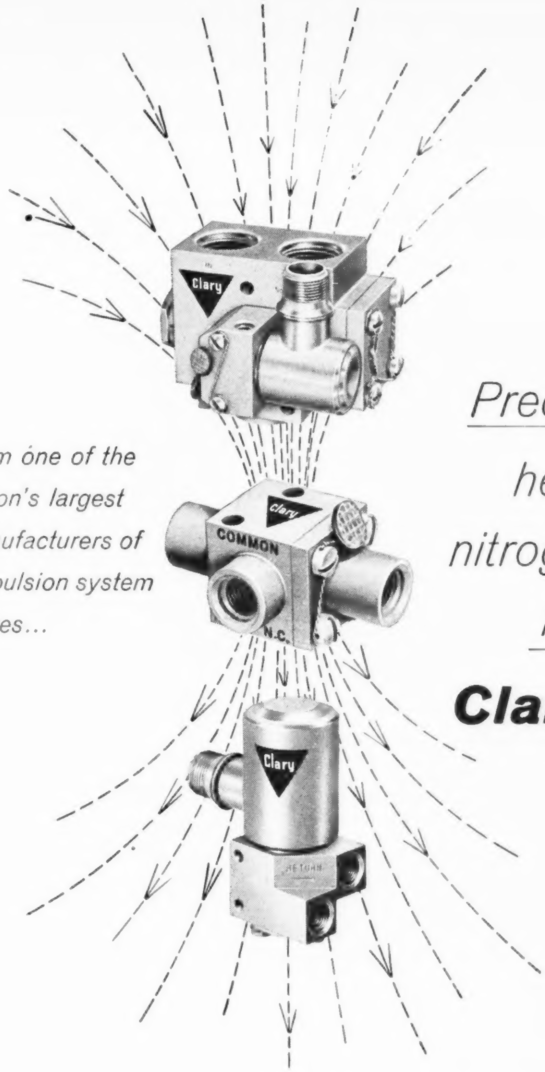
The Committee will meet in Paris at an early date and report back to ICSU and IAF not later than Aug. 15.

I undertook to raise the question of the reorganization of IAF at the forthcoming Congress, and I will propose that IAF be divided into two divisions —a Division of Natural Sciences, membership in which will be so constituted that regular affiliation may be possible with ICSU; and a Division of Social Sciences, members of which may be affiliated with other appropriate world organizations. The remarkable progress made in this connection is due largely to Dr. Berkner and his colleagues in the Bureau.

° ° °

Next, I proceeded to Hamburg and thence to Berlin, where I lectured before the Berlin group of the Deutsche Gesellschaft für Raketentechnik und Raumfahrt. I then departed to attend several meetings within the Iron Curtain, my first stop being East Berlin.

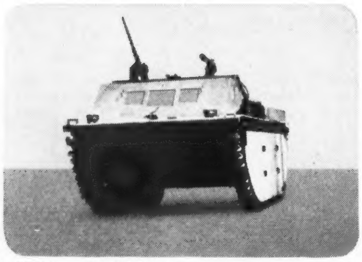
Next month's report will deal with my visits behind the Iron Curtain, in Scandinavia, in Southern Europe, and finally in Paris and London, as well as with the extraordinary program scheduled for the Amsterdam IAF Congress and on the new societies which are being organized.


Clary
Clary
COMMON
N.C.
Clary

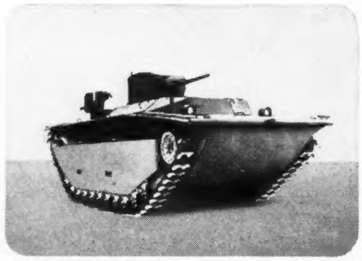
...speaking of

Missile Ground Support ***MOBILITY***

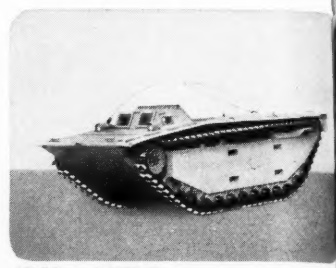
HERE'S WHY FMC CA



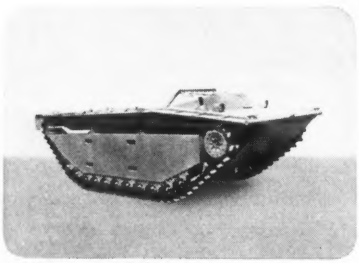
1941...LVT 1
Amphibious Personnel-Cargo Carrier



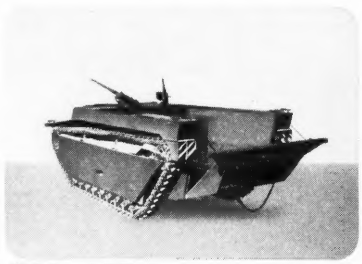
1942...LVT (A) 1
Amphibious Armored Assault Vehicle



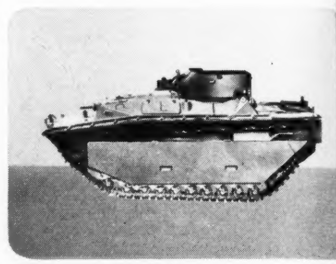
1942...LVT 2
Amphibious Personnel-Cargo Carrier



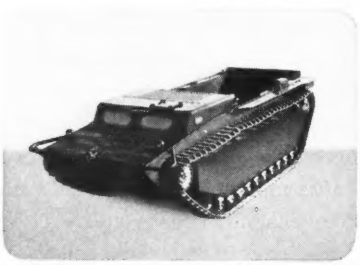
1943...LVT (A) 2
Amphibious Armored Personnel-Cargo Carrier



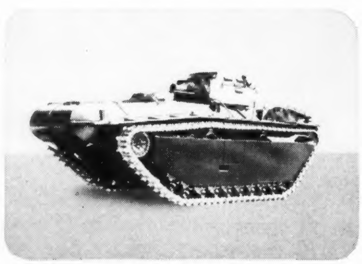
1944...LVT 4
Amphibious Personnel-Cargo Carrier



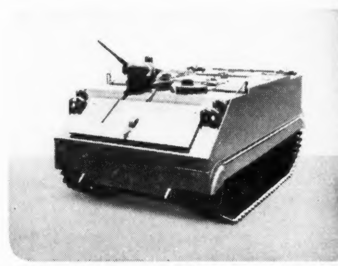
1944...LVT (A) 5
Amphibious Armored Assault Vehicle



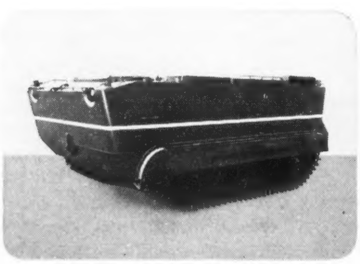
1945...LVT 4 Lightweight
Amphibious Personnel-Cargo Carrier



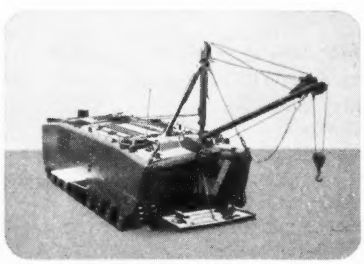
1949...LVT (A) 5 Modified
Amphibious Armored Assault Vehicle



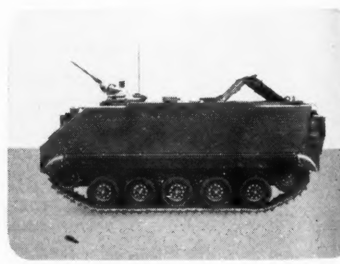
1951-1958...M59
Armored Personnel Carrier



1954...LVT P6
Amphibious Armored Personnel-Cargo Carrier

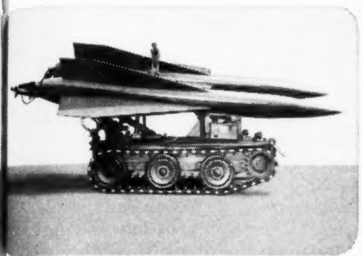


1955...LVTR-1
Modified Vehicle for recovery duty



1957...M-84
Mortar Carrier Vehicle

HANDLE MISSILE LAUNCHER PROGRAMS



1957...HAWK
Mobile loader Vehicle

1958...THOR
Transporter-erector Launching Mount & Power Control Trailer

FMC's development of ground support equipment for major missile projects stems from over 17 years experience in producing mobile surface equipment for the Armed Forces

Since 1941, FMC has designed and built more types of military-standardized tracked vehicles than any other company in America. This extensive and versatile background in the field of mobility can be applied to your missile ground support project.

FMC is uniquely qualified to handle every phase of the job from design concept through development, engineering, and production on any size project. Long familiarity with military requirements enables FMC to approach basic design with standardization in mind. With fully integrated facilities devoted exclusively to the production of defense equipment, contract delivery requirements are met—on schedule.

Do what others have done. Provide for the over-all success of your missile system, by contacting FMC at the very beginning of your program. This will insure perfectly coordinated development and delivery of required ground support equipment. Contact us today for more information.

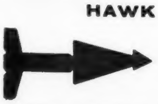
Creative Engineers: Find stimulating challenge at FMC's Ordnance Division

FMC'S MISSILE EQUIPMENT PROJECTS:

HAWK — Mobile loader vehicle

THOR — Transporter-erector & power control trailer

REDSTONE — Tracked prime mover



NIKE-HERCULES — Shipping and storage containers

BOMARC — Erector-launcher and Decontamination system

NAVAHO — Transporter-erector & vertical access tower

Putting Ideas to Work

fmc
FOOD MACHINERY AND CHEMICAL CORPORATION ®

FOOD MACHINERY AND CHEMICAL CORPORATION

Ordnance Division

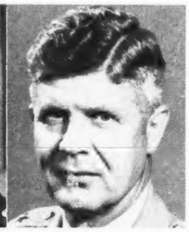
Missile Equipment Section 2-A

1105 COLEMAN AVENUE, SAN JOSE, CALIF.

Army Sets Up Unified Missile Command

The Army has announced integration of its key installations in rocket, missile and satellite programs under the direction of a single, newly formed U.S. Army Ordnance Missile Command, to be located at Huntsville, Ala. Maj. Gen. John B. Medaris, present head of the Army Ballistic Missile Agency, will head the Command.

Medaris



Shinkle

Barclay

Toftoy

The new command embraces ABMA (including the ABMA Project Office at Cape Canaveral, Fla.); Jet Propulsion Laboratory; Redstone Arsenal, renamed the Army Rocket and Guided Missile Agency; and the integrated White Sands Proving Ground.

Maj. Gen. H. N. Toftoy, former Commanding General, Redstone Arsenal, is Deputy Commander of the new organization. Heads of the subordinate agencies are Brig. Gen. John A. Barclay, ABMA; Maj. Gen. Waldo E. Laidlaw, White Sands Proving Ground; William H. Pickering, JPL; and Brig. Gen. John G. Shinkle, ARGMA.

Large-Scale Captive Tests

(CONTINUED FROM PAGE 49)

be made and what must be changed or can be changed. We are looking for system under-performance, marginal performance and over-performance. The action to be taken in under-performance is obvious. In the case of marginal performance, is the margin sufficiently high to prevent random variation from producing low reliability? In the case of over-performance, redesign is probably in order to reduce weight, and thus improve flight performance.

To determine "margins" adequately, a variable environment is usually necessary; otherwise, the quantities of test hardware to establish confidence from statistical data become prohibitive. Captive testing does not offer a variable environment in vibration, temperature, sound level, etc. It does, however, give a measure of these for defining pre-launch conditions. Then environmental variations can be applied to components in the test laboratory to determine the margin.

In this area, the captive test does offer a composite environment hard to duplicate in the laboratory. In this sense it is a "proof" test. It might be said that captive testing tells us *what* must or can be changed, but if we also ask *why* and/or *how much*, in detail, the test may become too cumbersome to be practical.

In areas where "cutting and trying" or variable juggling is necessary, separate special-purpose test stands are in order. Examples of these are a propulsion test stand with heavy-wall tanks permitting, among other things, a study of pump inlet conditions under pressure-simulated high G loading, and an autopilot test stand that can operate in conjunction with computing equipment.

One of the most important things captive testing offers is an opportunity to examine hardware *after* a test. In flight, we are dependent entirely on telemetered data and further testing for our analysis of failures.

Another very important aspect is that, in spite of a missile's relatively short operational life, it does have more life than that necessary for a single flight. Depending on circumstances we can get from five to 10 equivalent flights from a captive missile. Normally, we do not attempt to fly captive test missiles.

Objectives of Tests

In addition to the above, the following self-explanatory objectives should be considered:

Reduction of hazard with a step-by-step approach in the early phases; proofing missile system compatibility; proofing missile-to-ground support equipment compatibility; proofing and perfecting procedures; pre-flight proofing of changes; post-flight investigations of failures; training of launch personnel; and gathering reliability data.

There is no unique solution to the task of devising an instrumentation and data reducing system. From the above, it is obvious that there are certain basic requirements. These can be broken down as follows:

1. *Organization:* At Convair-Astronautics, field testing is treated as "engineering testing," and as such has the dual function of design evaluation and "experimentation." By "experimentation" is meant the obtaining of data in areas where theory does not permit sufficiently accurate prediction, the object being product improvement through knowledge improvement.

Report to Chief Engineer

Since field test is logistically peculiar to itself and serves all engineering, it reports directly to the chief engineer through an assistant chief engineer for field test. Under the assistant chief engineer are the test base managers and the chief of field test engineering. Reporting to the latter are the two groups in which we are mainly interested: The Test Planning and Test Evaluation Groups.

The Test Planning Group has the responsibility for producing the overall test plan as well as a plan for each missile. They accomplish this by coordinating the following primary factors:

Customer requirements (Specifications, etc.)

Designer and technical group requirements

Missile availability and configuration

Test stand availability and capability

Change hardware availability

Requirements for proof testing before flight

Test evaluation functions

The details of the instrumentation requirements to accomplish the objectives of the test plan are the responsibility of Test Evaluation. Test Evaluation coordinates technical details between the missile designers, technical groups and instrumentation designers to assure that data obtained will adequately answer the requestor's questions, i.e., satisfy the objectives. These activities result in an IBM instrumentation list that is the basis for all missile installations and field operations. Each measurement is keyed to missile, test objective and priority.

One of the most important functions of the group in creating this list is the extensive analysis of each measurement to make certain of its necessity and usefulness. This is the means by which the number of measurements are controlled. This will be discussed in greater detail below.

Test Evaluation also assists the test conductors in the analysis of "quick look" data; performs and/or directs

data reduction; performs data analysis to determine accuracy and internal consistency; performs and assists the designers in system analysis; correlates all data and issues reports; and runs a continuous statistical analysis of instrumentation performance as it influences data quality.

2. *Measurement Selection:* This is one of the most critical functions in the whole instrumentation operation, requiring the best talent available. It is not just a matter of being an arbiter between the designer and the tester; it is the point in the closed loop where a little common sense does the most good. Measurement selection might be called the stabilizing factor on the designer's desire to get all the information he can and the desire of the tester to do a good job for the designer.

Probe Into the "Why"

Extensive probing into the "why" of a measurement is necessary to make certain that the data is worth the cost in dollars and/or schedule time. The task is difficult in captive testing of missiles because it is not just one designer's desires that must be considered. There are 30 different systems, each with its own designer. If all the desired measurements were simply added together, the total could go as high as 1200. This is obviously an impractical instrumentation task.

A reasonable approach to measurement selection requires an intimate knowledge of the system under consideration *and* the history of system testing up to this point. With this, critical measurements can be found which give the most information for the least effort and cover those areas where trouble is most likely. Broad and/or detailed coverage should be accomplished in laboratory testing of system and component. Where possible, captive test should be looked upon as a "proof test," not as an "analytical test."

As a starting point, an accomplishable number of measurements may be estimated. With the aid of the chief designer this measurement capability may be apportioned among the designers, or systems, in accordance with the complexities of the problems and schedule importance of the system. The designer, working with Test Evaluation, can arrange his requirements in a priority list. This will enable Test Evaluation (and the chief designer) to reapportion if desirable.

The act of placing measurements in a priority list, if done intelligently, requires a searching study of "Why?" and "Is it really worth it?" compared with other measurements. By the time this process has been repeated several times the 1200 measurements come down to possibly 600. By distributing these measurements among several missiles, and in different tests on any one missile, the maximum number for any one test should be 300, with an average between 200 and 250. These figures are only typical and will be higher in the early part of the program than later on. The table on page 49 shows a typical case, with distribution as to type of measurement.

It is impossible to draw up some general rules for determining measurement priority. Each measurement must be analyzed on its own merits. One of the best approaches is to make a check list containing questions like the following:

Is this measurement to be combined with other data to satisfy an objective? If so, with what accuracy are other data known? Is the final result of sufficient accuracy to satisfy the basic objective?

Is this information implicitly contained in measurements already being made? Can it just as well be calculated?

Is this measurement solely to prove that design assumptions were correct? If so, system testing may answer this as well, if not better, than captive testing.

What will happen if we do not obtain this measurement? Will we hold up a flight?

What is the real fundamental objective we are trying to determine? Forgetting the proposed measurement for the moment, is there an entirely different approach that would be as good and much simpler?

What has been changed in the system that we now have to remeasure or continue to measure this quantity?

What has been our experience in leading us to think we need this measurement?

Is the measurement needed for safety? For control?

Is this a measurement we might wish we had in case of a failure? (This can be overdone.)

Is the accuracy asked for absolute accuracy, or do we just want to read small differences? That is, is it sensitivity or accuracy?

Can this measurement be made with low accuracy now and, if it looks critical, measured with higher accuracy later?

Can we measure transient behavior on an oscillograph with high time accuracy and low magnitude accuracy? Can steady state magnitude be simultaneously measured on a slower-acting, more accurate instrument?

Can low- and high-range transducers be used simultaneously to reduce accuracy requirements?

3. *Controls, Planning and Evaluation:* In a sense, planning controls testing, but planning in turn is controlled by many factors. The results of tests, availability of hardware, the designers' desires, etc., are but a few of these factors.

Determine Extent of Changes

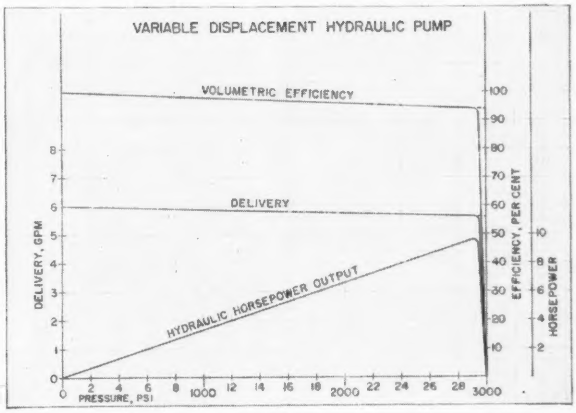
Where a number of test stands are operated simultaneously, one of the biggest problems is that of determining the extent of missile design change incorporation prior to missile change. Keeping all systems up to date continuously is an almost impossible task. It overburdens the Production Department for hardware, to say nothing of slowing up the test program. The over-all program is divided into several phases, but, in addition, systems on particular missiles are assigned either primary or secondary priority. The primary systems are kept up to date and are the subject of study on their particular missiles. The secondary systems are kept functioning, but only mandatory changes are incorporated. This speeds up the program and reduces the instrumentation task.

In addition to this, tests are planned

Scorched X-7

This AF X-7 test vehicle, powered by new Marquardt ramjet engines, flew so fast its bright yellow paint job was burned black. The recoverable vehicle was developed by Lockheed and is said to have set new speed and altitude records for air-breathing vehicles in recent flights.

New Hydraulic Pump for 550° F and 12,000 RPM Service



Sizes and capacities designed to meet your requirements

This new Sundstrand hydraulic pump successfully meets the need for a lightweight, compact unit capable of operating at elevated temperatures with high reliability. Note that it is rated for service to 550° F *inlet oil*, as well as ambient temperature.

In addition to the .125 cu. in pump illustrated, other sizes will be available as required.

The new pump is a result of a continuing Sundstrand program which is crossing previous temperature barriers for hydraulic components. Inquiries on requirements in high-temperature areas are invited.

Mail coupon for complete technical data on the new Sundstrand pump for high-temperature service.

SUNDSTRAND

SUNDSTRAND AVIATION

Division of Sundstrand Machine Tool Company, Rockford, Illinois

Sundstrand Turbo, Denver, Colo. • Western District Office: Hawthorne, Cal.

Characteristics of Pump Illustrated

- **Flow: 6 gpm**
- **Speed: 12,000 rpm rated, overspeed to 18,000 rpm. rapid acceleration.**
- **Temp. Range: –65° F to 550° F *inlet* and ambient.**
- **Inlet Pressure: 60 psig.**
- **Discharge Pressure: 3000 psig.**
- **Cutoff: Maximum full flow pressure to zero flow pressure within 50 psi.**
- **Displacement: 0.125 cu/in. rev.**
- **Weight: 5.0 lb.**
- **Size: 4.344" over-all length, 4.452" over-all width.**
- **Lubricant or Fluid: Any of those common to aircraft applications.**
- **Volumetric Efficiency: 94% at rated speed and pressure.**
- **Mil Specs: Characteristics conform to MIL-P-7740B Type IV System.**

Sundstrand Aviation
2419 Eleventh St., Rockford, Ill.

Please send data on pump for 550° service.

Name__________

Title__________

Company__________

Address__________

City__________ State__________

☐ Immediate ☐ Reference

in blocks of three or four firings. Incorporation of changes during a block is avoided. Each block has general, over-all objectives, but the particular firing on which any one must be accomplished is not specified except where mandatory. This helps by allowing some latitude of operation to meet field contingencies without planning changes.

With missiles assembled on a production line, planning and measurement analysis must lead the test by the order of 12 months to permit procurement and drawing release of instrumentation. This also means that instrumentation changes must be accomplished in the field.

As part of data evaluation, a continuous statistical study is being carried out on the accuracies (drifts) of all elements of the "data producing system." Each measurement has its own over-all transfer function, made up of the transfer functions (calibrations) of each element of the system. All measurements are stored and indexed on IBM cards, so that, in a very short time, a tabulation of a variable for every time it has been measured can be produced.

These, then, are the main considerations governing the captive testing and instrumentation of large missiles. There are many by-products of captive missile tests, but the primary purpose is still to obtain sufficient accurate measurement data under known and/or controlled conditions to evaluate progress and increase knowledge to permit further progress.

Management and control of such tests through procedures such as those outlined here can go a long way toward assuring that the tests accomplish these objectives.

• • •

Another article by the author, dealing with the technical and operational aspects of the instrumentation system for large-scale captive missile testing that results from the considerations discussed here, will appear in an early issue of ASTRONAUTICS.

Japan Fires Plastic Rocket

TOKYO—Japanese scientists are reported to have successfully fired an all-plastic rocket near Akita, on Japan's northwestern coast, in February. Tokyo University experts said the rocket had risen to an altitude of 7200 ft, reaching a maximum velocity of Mach 3. The flight took 40 sec. The rocket, designed by Hideo Itokawa of Tokyo University, was 9.2 ft long and 51 in. in diam, and weighed 78 lb.

—R.L.

from the patent office

BY GEORGE F. McLAUGHLIN

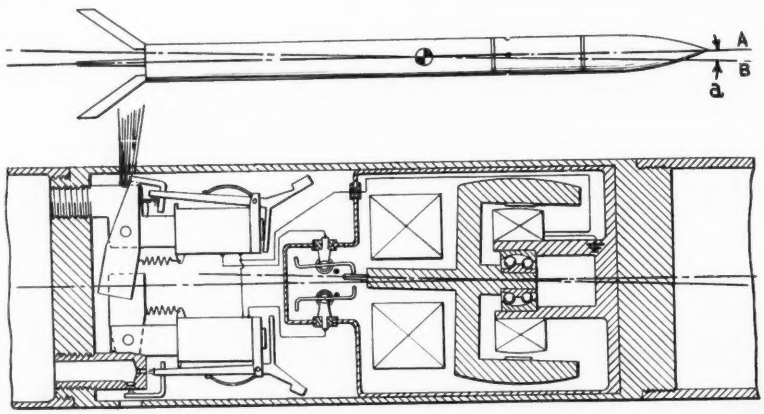
Auxiliary Jets Keep Rocket on Target

Jet-propelled missiles which maintain a desired heading by use of a simple control mechanism have been patented by a major aircraft company. Gases from the propellant operate the flight control mechanism in the devices, selectively interfering with the jet action in the sides of the missile to keep it on target.

Connected to the propellant chamber casing, a stabilizer is provided with ports spaced 90 deg apart and ahead of the center of gravity of the rocket. Each of four hollow plugs, threaded into the dividing wall between the chamber and the stabilizer, has a discharge nozzle in line with one of the ports. An electromagnet mounted on each plug has a lever pivoted to a support on the magnet. An armature is connected to the lever which also has a counterweight. A spoiler pivoted to each plug is aligned with the nozzle, and deflects or blocks the gases from the nozzle to nullify the jet force. A bracket is connected to each spoiler, one arm of which is located opposite a corresponding auxiliary nozzle in the plug. The lever is placed opposite the nozzle so the jet will not be effective on the bracket. A spring moves the lever toward the magnet and against the action of the electromagnetic force. A coil spring connected between each magnet and its associated spoiler holds the spoiler opposite the nozzle.

Each electromagnet is capable of being energized from a generator in one end of the stabilizing unit. A gyroscope of the run-down type is mounted within the generator support and controlled by an inertia-actuated uncaging device. The device holds the gyroscope axis parallel to the rocket axis until launching acceleration occurs. The gyroscope shaft has a pick-off member positioned between pick-off arms mounted in the casing. Each arm is electrically connected to one of the electromagnets which, in turn, is connected to the generator. The coils and one side of the generator are grounded, completing the electrical circuit.

Before launching the missile, the gyroscope is brought to speed by external electrical power, the generator functioning as a motor for this purpose. The gyroscope is uncaged by the acceleration of launching. Thereafter, the gyroscope axis remains parallel to its direction at the time of uncaging. During the burning period, hot gases from the rocket's propellant flow through each control plug. When the rocket is on its intended heading, the flow from each discharge nozzle is spoiled by impingement against the spoiler, which is held in position by springs.



Exterior and sectional views of mechanism for flight stabilization by gyroscopically-controlled jets on four sides of rocket body, forward of c.g.

In the accompanying drawing, assuming that line A is the intended heading of the rocket and that the rocket axis shown by line B has deviated from course by angle *a*, the rocket, will be displaced with reference to the gyroscope and the pick-off will engage one of the arms, completing the electrical circuit through one of the electromagnets. This will energize the magnet, causing the lever to move against the spring action, uncovering the auxiliary nozzle. Gases from the auxiliary nozzle strike the bracket, shifting the spoiler and permitting gas to discharge through its port. The jet from the nozzle creates a thrust which will rotate the rocket about its c.g. on an axis at right angles to the longitudinal axis. When the axis of the rocket is aligned with the intended heading through the rotational axis of the gyroscope, the energized circuit to the electromagnet is broken, the spring will re-position the spoiler over the discharge nozzle, and the lever will be positioned opposite the auxiliary nozzle.

The device is of particular value in rockets launched at high altitudes, or from fixed surface launchers. It is applicable to rockets launched from aircraft at angles to the relative wind, including those launched rearwardly. Having no external aerodynamic surfaces, the rocket has desirable logistical advantages, including adaptability for internal storage in a launching vehicle, ease of handling and tube launching.

Patent No. 2,822,755. Flight Control Mechanism for Rockets. L. K. Edwards, L. Lowell, and A. J. Summers, assignors to McDonnell Aircraft Corp.

Supersonic Vehicle for Testing Electronic Guidance Equipment

Patents on a means for flight testing missile control systems have been assigned to the U.S. Navy. The invention is a vehicle having a conical nose with space for the equipment to be tested. After experimental equipment has passed subsonic tests, it is further tested at supersonic speeds; this results in economy by weeding out simpler defects before subjecting the equipment to the more exacting supersonic tests.

A central sustaining rocket is housed in the rear part of the missile and two launching rockets are mounted at either side. In operation, the missile is launched from a pair of T-section launching rails. When the launching rockets are spent, air drag causes the carriage to slow down and drop from the missile.

The equipment under test is controlled by signals received by the missile using internal horn antennas with conductors leading to the mechanism.

Patent No. 2,824,711. Vehicle for Testing Control Systems at Supersonic Speeds. Henry H. Porter, Washington, D.C.

Fundamentals of Guidance

(CONTINUED FROM PAGE 24)

the radar beam, and the other, the target flying at right angles to the radar beam.

In the first case, the correct path for the missile lies along the beam, and the missile can be caused to return directly to the center of the beam by pitching alone, if the error is all in the traverse direction, or by yawing alone, if the error is to the right or left and parallel to the elevation axis. Significantly, for this case there is effectively no coupling between pitching and yawing error corrections.

In the example of the target flying at right angles to the beam, the correct path of the missile, if it is to ride the beam, is in part determined by a component of velocity at right angles to the beam. This lateral component is proportional to the corresponding component of target velocity, multiplied by the ratio of the missile distance from the radar to target distance from the radar. The result is that the missile assumes an orientation in the beam which is oblique to the beam axis. If missile speed is twice that of the target, this angle of obliquity can reach 30 deg at impact.

Might Contain Vertical Gyro

The missile might contain a vertical gyroscope, the outer gimbal axis of which lies along the missile roll axis. This allows the inner axis of the gyro gimbal system to be horizontal. If the missile is roll-stabilized so that its pitch axis is parallel to the inner gimbal axis, it can be seen that a pitch signal will tend to reduce the error parallel to the radar traverse axis. However, the missile pitch axis is not parallel to the radar elevation axis, and hence a part of the pitch correction will appear parallel to that axis, resulting in an elevation error. This error must in turn be corrected by a yaw signal, the result being a coupling between the pitch and yaw modes which will tend to cause the missile path to spiral about the radar beam axis.

Thus it can be seen that, even in such a seemingly simple guidance system as that of a beam-rider missile, system operation is intimately dependent upon the coordinate axis relations of the guidance equipment (ground radar) and the missile's onboard angular reference (the vertical gyro), as well as the mode of roll-stabilization employed. Similar complications arise to a greater or lesser extent in nearly every type of missile guidance system for use against moving targets.

Two other common guidance schemes for nearby, moving targets are command systems and homing, or target-seeking, systems.

A command system is one in which a "pilot" or computer in a remote location guides the missile by radio or other signals. Optically piloted, wire-guided missiles can be considered for short-range use against stationary or slow-moving land targets. An example will be found on page 23. Here the missile is launched in the general direction of the target, and the pilot, who can see both target and missile visually, keeps the missile on the line of sight to the target by simple up-down and left-right signals, sent along trailing wires to the simple autopilot in the missile. The guidance problem in this case is reduced to a two-dimensional one, and no coordinate transformations are required if the missile makes flat turns.

A somewhat more general command system application is shown on page 23. Here the target is an aircraft, moving past the ground defensive installation. Ground radars obtain range, elevation and azimuth data on both missile and target. A ground computer calculates corrections to the missile's path as required to secure a hit. These corrections are then transmitted via a radio link to the missile, where they are received and interpreted by the missile's computer and reference system as autopilot signals.

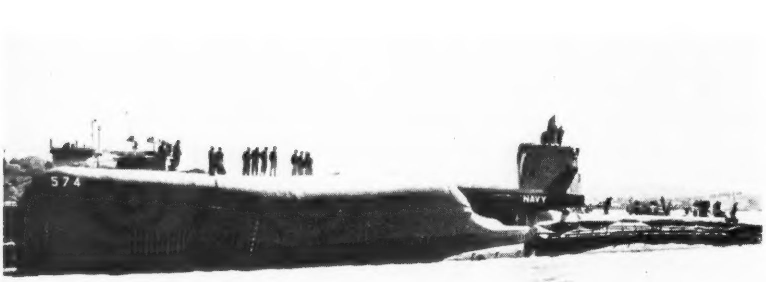
Target-Seeking Systems

Target seekers, or homing systems, are those which detect some distinctive pattern of energy radiated or reflected from the target and use this source of radiation to give steering signals to the missile. Homing systems are usually classified as active, semi-active or passive. In an active system, the missile itself carries a radar or other energy transmitter with which it illuminates the target. It then receives and interprets the echoes to provide steering information. In a semi-active system, the target-illuminating energy comes from an outside source, such as a ground radar or radar in an interceptor aircraft. Here the missile has only radar receiver and steering mechanisms. In a passive system, the target is detected by some radiation of its own, such as infrared radiation from a jet engine.

The most direct approach to a target-seeking system is to point the missile at the target and simply tell it to steer toward it. Simple as this type of guidance sounds, it presents a difficult computation problem when coordinate systems are taken into account, much as in the beam-rider system already discussed.

Some of the various seekers and homing devices in use today are developments of this basic idea: To hit a target, always steer toward it. It often happens, however, that the most efficient path to a target, especially a moving one, is not attained by flying directly toward it. As may be seen in the drawing on page 24, the path of a missile steering toward a moving object (a pure pursuit path) becomes sharply curved as the object is approached. In fact, for a missile which flies somewhat faster than the target, an indefinitely large turning rate will be required in a pure pursuit attack. A dog running across the lawn after a rolling tennis ball often discovers this to his dismay. Because the maneuverability of any missile is limited, it has become necessary to develop homing guidance systems incorporating other modes of operation.

One type of path which decreases the turning rates required of the mis-



Missile-Firing Submarine

Twin cylinder-shaped hangars faired into this submarine's upper hull, forward, were designed to carry and fire supersonic Regulus II and other guided missiles. Ship is the Navy's newly commissioned Grayback.

sile is the constant bearing course, in which line of sight from missile to target maintains the same direction in space. Proportional navigation, illustrated on page 24, in which the turning rate is proportional to the absolute angular velocity of the line of sight (usually measured by rate gyroscopes) can result in a path intermediate between the pursuit course and the constant bearing course, depending upon the proportionality constant used. For a true constant bearing guidance system, this proportionality constant is infinite.

Limited to Small Ranges

Homing systems, in general, have the unique advantage of providing increased signal strength and accuracy where it is needed most—near the target. Signal strength falls off rapidly with distance, however, so these devices are generally limited to ranges of not more than a few miles.

For distant stationary targets, such as factories, shipyards, etc., the missile is apt to be large, to contain the necessary fuel and warhead. Extreme agility is not required, but extreme speed is.

There are two ways to take a load of explosives rapidly to a distant target. One is to fly it; the other to throw it.

The word "ballistic" actually comes from a Greek word, meaning to throw. (The philosophically inclined reader may like to trace, in the dictionary, its close connection with "diabolic.") In a ballistic missile, a tremendous initial push (or sequence of pushes) is given against gravity, to throw the missile. It then falls on the target in a trajectory or orbit determined primarily by gravity.

The guidance problem is to get the initial velocity and directions just right, since opportunities to correct matters, after the initial shove is provided, are very limited.

A strictly self-contained guidance system is available which can perform all the necessary measurements and computations with virtually unlimited potential accuracy—an inertial guidance system.

Inertial guidance is based on Newton's laws of motion, and requires no outside reference other than the gravitational field of the earth. If a known mass is supported in any vehicle, a force will have to be exerted on the mass to accelerate it when the vehicle accelerates. The amount of force required, which can be measured, is a direct indication of the accelerations acting on the vehicle. Three acceleration measuring devices, called accelerometers, can be mounted orthogonally and will give complete acceleration information in three dimensions. If the initial position and velocity of the missile are known, it is possible to compute the new position and velocity at any time by adding up all the accelerations which have occurred from the time the system was activated. Thus a completely self-contained position and velocity reference is attained.

The accelerometers must be supported in a known orientation with respect to the earth so that the direction of each acceleration is known. This is usually accomplished by mounting the device on a platform which is gimballed, to free it from missile attitude changes, and which is held in a known orientation by means of low-drift stabilizing gyros, as shown on page 23. The accuracy of such a system is critically dependent on the precision of the accelerometers, and is only slightly less dependent upon the drift rates of the stabilizing gyros, for while the boost time in ballistic applications is short, the severe acceleration environment imposes critical problems in their design, fabrication and adjustment.

When a gun is used to hit an invisible target, it is necessary to know the location of the gun just as accurately as the location of the target. The same considerations apply to the ballistic missile guidance problem. On land, maps of the launch area are generally available, but in launching from a surface ship or submarine, the establishment of position to the required accuracy poses a definite problem. Traditional navigation techniques are just not good enough, and considerable effort is being directed toward increased accuracy of surface navigation.

For some space flight applications, guidance can be of the ballistic type. The orbit required to carry a space vehicle to a desired destination can be computed with considerable accuracy. If the vehicle can then be placed in this orbit with the proper speed and at the proper time, the vehicle can "fall" all the way to the target. The speed and direction sensing accuracies required to achieve this type of control for some specific space and ballistic missile missions are shown on page 24. It should be noted that the guidance accuracy required to put a satellite in an orbit which varies in altitude over a range of several hundred miles need be only comparable to the V-2 system of World War II. Guiding an ICBM to a 10-mile target, on the other hand, would require far greater accuracy.

While winged (cruise-type) missiles are essentially unmanned airplanes, navigation techniques may be quite different from those used, let's say, in a commercial airliner. Radio methods have obvious limitations when the people at the destination do not really want delivery of the merchandise. Self-contained systems based on airspeed measurements, wind predictions and magnetic compass heading fall far short of the required accuracy.

Long-Range Automatic Navigation

Three methods have often been proposed for long-range automatic navigation. Doppler navigation, illustrated on page 23, makes use of a shift in frequency of reflected radar signals which is observed when the reflecting surface (e.g., the ground) is in motion relative to the transmitter-receiver. By using multiple beams (fore and aft and lateral), ground speed can be generated with considerable accuracy.

Because a Doppler radar is capable of measuring only the magnitude of the ground velocity vector, it is necessary to incorporate an accurate azimuth reference to resolve measured speed into components along the navigational axes. Thus the limiting accuracy of the system may well be determined by the accuracy of the azimuth reference. An error of 1 deg in azimuth produces an error of more than 10 miles in a 600-mile flight.

This type of system requires ac-

First Static Test for Titan

Exhaust clouds billow out of Titan ICBM engines in first static test of the missile's complete propulsion system at The Martin Co.'s Denver facility.


A bird in hand...
RADAR INTELLIGENCE
FOR ALL APPLICATIONS
Produced at
DAYSTROM INSTRUMENT
Fire Control Computer
Radar Console
Radar Antenna
Daystrom Instrument meets today's rigid requirements for Missile Control Equipment.
Our engineers and production specialists are qualified, ready and anxious to assist in your programs. Our new 350,000 sq. ft. plant is completely equipped with the most modern manufacturing and test facilities for the production of electronic and electro-mechanical products.
Be among our satisfied customers in the Armed Services and Industry. Contact us for complete information on how we can help you.
Remember—Reliability Is A Must At Daystrom Instrument.
DAYSTROM INSTRUMENT
Division of Daystrom, Inc.
ARCHBALD, PENNA.
IN CANADA: Daystrom Ltd., 840 Caledonia Rd., Toronto 10, Canada
EXPORT: Daystrom International, 100 Empire Street, Newark 12, N. J.

curate knowledge of the surface distance and direction to the target. Any error which arises remains in the system to the end of flight, since no actual position reference is being used. Applicability is limited to targets for which radar silence is not a requirement, and for this reason it is probably of limited use for missiles, unless combined with some other system.

In celestial navigation, principles of which are shown on page 23, and used in piloted aircraft or ships, angles between stars and the horizon, or the local vertical, are measured. Observed angles can be used, together with the star position data found in astronomical tables and an accurate time signal, to compute position on the earth. Two major difficulties make this, in its traditional form, an impractical system for use on missiles.

First, an accurate determination of the horizontal, or vertical, from a moving aircraft cannot be made with ordinary pendulous or liquid-level devices. In a Mach 1 missile, an undetected turning rate of 11 deg/hr (a circle of 3600 mile radius) in the horizontal plane will cause nearly 0.1 deg deflection in the vertical as observed by any gravity-actuated device in the missile. This much error in the apparent vertical will cause a 6-mile position error. Second, the tracking of celestial bodies in full daylight is difficult without an exceptionally stable base. However, as we shall see, certain combinations of celestial techniques with other systems can provide useful information.

The principles of operation and the major components of an inertial navigation system are almost identical with those in the ballistic inertial guidance system described earlier. The major differences are that, in the cruise missile, accelerations and speeds tend to be smaller and flight times longer than in ballistic applications, and there is no need for a vertical accelerometer in the cruise missile. The accuracy of the system depends primarily upon the precision of the stabilizing gyros and, to a lesser extent, the accelerometers.

Accuracy is largely independent of distance, although in general the errors increase with time in a non-linear way. A stabilizing gyro with a drift rate of 0.01 deg/hr (one revolution in four years) will cause a position error of about 0.6 miles per hour of flight. Instruments of better precision than this must be, and have been, designed to withstand shock, vibration and storage at arctic or tropical temperatures, and must still be as small and light as possible for use in practical inertial navigation systems.

Obvious advantages of such a navigation system are its complete independence of radiated information, with consequent invulnerabilty to jamming, independence of type of terrain, weather or time of day.

Each automatic navigation system discussed has some disadvantages which limit its usefulness in certain applications. Many current navigation systems overcome this problem by combining two or more of the above approaches in one system.

For example, the supervision of an inertial navigator by a stellar monitor results in a more accurate self-contained navigation system than either alone for long flight times. Stellar monitoring minimizes the cumulative errors due to gyro drift rate, while the stabilizing gyros provide the accurate vertical reference and the stable base which were seen to be necessary for daylight tracking of stars and effective use of stellar information. The combination also permits in-flight alignment after a hurried take-off.

The ultimate price of system combination is complexity, which may in turn result in increased weight and decreased reliability, although over-all reliability is sometimes improved by use of redundant system elements. The possible effects of increased complexity must always be considered carefully in the establishment of performance requirements for missile navigation systems.

TCEA Offers Free Courses In Specialized Aerodynamics

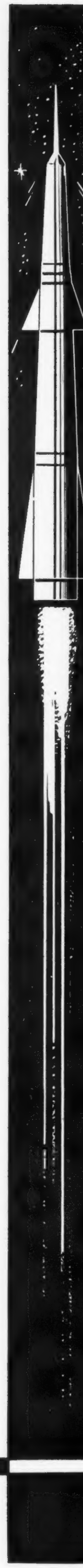
The Training Center for Experimental Aerodynamics in Brussels, Belgium, has opened enrollment to engineers and scientists of NATO countries for its nine-month free course of study starting Oct. 15, 1958 and ending July 15, 1959.

The course of study includes Wind Tunnels and Basic Instrumentation, Basic Electronics, Measurements in Steady Flow, Measurements in Non-Steady Flow, Boundary Layer Measurements, and Transonic and Hypersonic Aerodynamics. Courses will be held in English and French.

TCEA was jointly established in 1956 by the U.S. and Belgium as part of AGARD for express purpose of providing special training of young aeronautical scientists and engineers from NATO countries in the means and techniques of experimental aerodynamic research.

Entrance requirements include a M.Sc. degree, knowledge of incompressible and compressible fluid mechanics and fluent knowledge of either English or French.

Applications and a brochure describing TCEA are available from R. Paul Harrington, Technical Director, TCEA, 72, Chaussée de Waterloo, Rhode-Saint-Genese, Belgium.



Problems in Telemetry

(CONTINUED FROM PAGE 37)

The increase in received power scales as the square of the diameter, keeping the wave length fixed.

3. *Increase the effective area of the receiving antenna.* For an antenna of given directivity, such as a halfwave dipole antenna, the effective area of the antenna for intercepting radio power is proportional to the square of the wave length. As the antenna area is increased, holding the wave length constant, the directivity is increased. The ultimate limitation on antenna size is the phase scintillation due to atmospheric turbulence. However, structural limitations resulting from antenna tracking requirements, environmental effects, etc., will no doubt prevent the realization of the ultimate for frequencies which are practical in the foreseeable future.

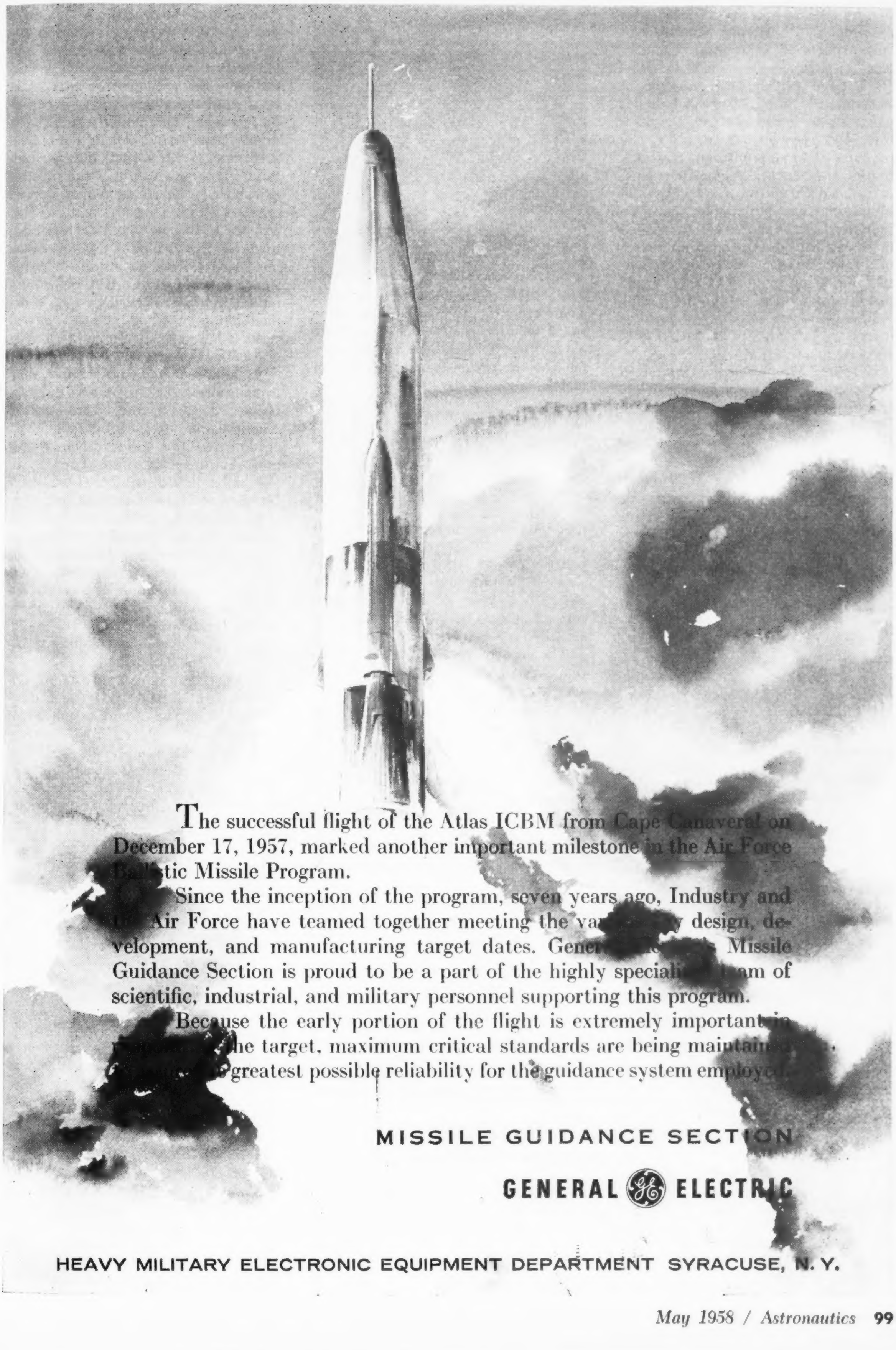
For the 220 mc telemeter frequency, a tracking antenna consisting of a dish 60 ft in diam has been constructed with a 30 db gain over isotropic and with a 5 deg beam width. It is doubtful that it will be practical to build an antenna with more than an order of magnitude larger area because of mechanical problems connected with tracking and environment.

4. *Reduce the noise generated by the radio receiver.* The processes of amplification, conversion to lower frequencies and signal demodulation, all add noise to that already present in the signal. In best current telemetry practice at 220 mc, the receiver adds noise equivalent to a thermal noise source with a temperature of 300–600 K. At higher frequencies, the noise output is larger, increasing smoothly into the microwave region. At 2200 mc, the noise added in best practice is equivalent to about 2000 K.

Noise Becomes Limiting Factor

For frequencies lower than about 200 mc, the noise added by atmospheric and galactic effects becomes the limiting factor even with current receiver practice. Solar radio noise must be considered, but only reasonably directive antennas can usually be placed so that the radio telemeter transmitter is not "lost in the sun." Man-made noise must be considered in all frequency bands and must be considered in reference to the particular location of the transmitter and receiver.

Current research activity in solid state elements points to considerable future reduction in the noise added in

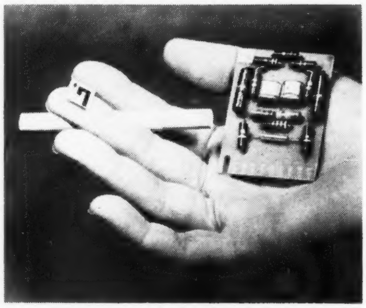

The successful flight of the Atlas ICBM from Cape Canaveral on December 17, 1957, marked another important milestone in the Air Force tic Missile Program.
Since the inception of the program, seven years ago, Industry and Air Force have teamed together meeting the design, development, and manufacturing target dates. Missile Guidance Section is proud to be a part of the highly am of scientific, industrial, and military personnel supporting this program.
Because the early portion of the flight is extremely important the target, maximum critical standards are being maintain greatest possible reliability for the guidance system employ
MISSILE GUIDANCE SECTION
GENERAL ELECTRIC
HEAVY MILITARY ELECTRONIC EQUIPMENT DEPARTMENT SYRACUSE, N. Y.

the process of reception. (See, for example, E. W. Herold, "Future Circuit Aspects of Solid State Phenomena," IRE Proceedings, vol. 45, Nov. 1957, page 1463.) For example, it is estimated that with crystal diodes operating at liquid nitrogen temperature, the receiver added noise can be reduced to an equivalent of 150 K for all frequencies below 10^5 megacycles. With masers (molecular amplification by stimulated emission radiation), it appears that the added noise can be reduced to an equivalent of a few degrees K or less in the carrier frequency range of 1000 mc and more by operating at liquid helium temperatures. Thus, future improvements are indicated of 10 to 20 db in receiver noise performance.

5. *Improve the efficiency with which the available radio frequency power is utilized in modulation and demodulation.* Right now, this appears to be the most likely area where several orders of magnitude improvement can be obtained, i.e., where range could be increased by an order of magnitude or more with the same radio transmitter power and output signal-to-noise ratios currently required.

It should be recognized that the method of detection or demodulation is greatly simplified in most applications, such as the conventional FM discriminator, at the cost of a considerable loss in efficiency. In general, optimum or near-optimum demodulation requires rather sophisticated operations on the received signal.

Award Winner



The 1957 Miniaturization Award, sponsored by Miniature Precision Bearings, Inc., went to Diamond Ordnance Fuze Laboratories for development of the extremely small transistor (left), compared with ordinary present-day transistor (right). Diamond utilized photolithographic processes and printing techniques for its transistor.

Process Has Two Stages

The process of demodulation can be conveniently divided into two stages. The first stage is the determination, for each combination of signal and noise received at the input of the demodulator, of the *a posteriori* probability distribution over all the data signals that might have been sent. Such determination requires knowledge of the *a priori* probability distribution of the data signal source, together with the conditional probability distribution describing the random noise errors occurring between the signal source and the demodulator. The *a posteriori* probability distribution provided by the first stage contains the maximum information regarding the data signal.

One practical difficulty that sometimes occurs in carrying out this first stage of demodulation is a more or less incomplete knowledge of the *a priori* distribution of the data signal source. However, some distribution must be assumed in order to carry out demodulation, and any resulting error in the *a posteriori* distribution will in general reduce the efficiency of demodulation. Sometimes it is possible to improve the knowledge of the *a priori* distribution by analyzing the received signal, and so it might be desirable to carry out final demodulation at a convenient time after the signal is first received.

The second stage in the demodulation process consists of making a decision from the *a posteriori* probabilities regarding which data signal was originally sent, for the demodulator must deliver some output (demodulated) signal. Such a decision, involving the selection of a particular signal from the *a posteriori* distribution, can be made only on the basis of a criterion such as maximum likelihood, minimum mean square error, minimum mean absolute error, etc., and will in general involve a loss of information. That is, once a demodulated signal is obtained on the basis of one criterion, it is usually not possible to obtain from it the demodulated signal on the basis of another criterion.

It is possible to refer to "optimum demodulation" only with reference to a particular decision criterion, the choice of which should depend on how the telemetered data are to be used. For example, in a certain case, the usefulness of the data depends on the error in the following way. When the error is anything less than e_1 the data are completely useful, and when the error is greater than e_2 (where $e_2 > e_1$), the data are completely useless. Thus, the criterion should be the minimization of a function of the error which is zero when the error is less than e_1 and which is some constant when the error is greater than e_2 and which varies in some appropriate way between e_1 and e_2.

Often, when the telemetering signal is first received, it is not known just how the data will be used; that is, a proper decision criterion cannot be chosen. Or perhaps it will be desirable to have demodulations in accordance with several different criteria. In such cases, it is not possible to carry out "optimum demodulation" once and for all at the time of first reception, and it would be desirable to defer the demodulation operation until later. This means the received signal should be recorded before demodulation, with the appropriate demodulation method being accomplished later, as the forepart of data reduction.

In addition to taking care of any initial uncertainty regarding the decision criterion in the second stage of demodulation, such predetection recording has the added advantage of not requiring at the time of reception, the probability distributions necessary for the first stage of demodulation.

It should be understood that, in general, the determination of the value of an optimum demodulated signal for a given time requires the future (as well as the past) values of the received signal for an interval of t_c on each side of the given time, where t_c is the longest period of any significant correlation in the data signal.

Thus, if anything approaching optimum demodulation is to be accomplished, with the attendant important reduction in required RF signal-to-noise ratios, it is most desirable that primary telemetering reception and recording be an essentially linear process, without any attempt at demodulation. This would give what might be called "a universal telemetry receiving station" which would receive any combination of signal and noise in an appropriate pass band, translate (mix) it to a lower frequency, and directly record it.

Procedure Is Feasible

Recent advances in the state of the art of magnetic recording, primarily for TV video recording, appear to make such a procedure entirely feasible for pass bands up to several megacycles bandwidth. The same primary receiving station could equally well handle FM-FM, PDM-FM, PPM-AM, PCM-FM, etc. The proper demodulation operations would then be determined and carried out later, using either special equipment or perhaps in some cases the same large-scale computer used for subsequent data reduction and analysis operations.

With the telemetry transmitting equipment currently in use, it appears that the greatest improvement to be made by application of optimum demodulation techniques is with FM-FM and its variations, such as PAM-FM-FM and PDM-FM-FM. This was pointed out some time ago (F. W. Lehan, *Telemetering and Information Theory*, IRE Transactions on Telemetry and Remote Control, November, 1954, page 15) by means of certain suggestions of improved methods for demodulation of FM and FM-FM. The phase-lock loop (S. R. Margolis, *The Response of a Phase-Locked Loop to Sinusoid Plus Noise*, IRE Transactions on Information Theory, Vol. IT-3 No. 2, June, 1957, pge 136) used singly and in combination is not an optimum demodulation method, but it is a considerable improvement over the conventional FM discriminator, and is not difficult to design and operate.

Subsequent discussion will consider the phase-lock loop, but it should be kept in mind that there remains very much more to be done along the lines of optimum demodulation and what has been done is much ahead of available telemetering practice.

Improves Signal-Noise Ratio

In wide-band modulation methods, such as FM, PDM, PCM, etc., modulation is spread over a larger radio frequency bandwidth than the frequency band of the information to be transmitted. This amounts to an exchange of radio frequency power and bandwidth and, in accordance with information theory, can lead to an improved signal-to-noise ratio in the output of the radio link. But the wider the RF bandwidth, the more noise is mixed in with the RF signal at the receiver. With conventional demodulation methods, there is a signal-to-noise ratio in the RF band below which the output signal-to-noise ratio rapidly deteriorates, as shown in the graph on page 37.

The carrier signal strength at which the output signal-to-noise ratio breaks is called a threshold, and threshold signal strength is larger for larger effective RF noise bandwidth. A similar situation exists in the pulse systems, such as PPM, PDM and PCM. With the conventional AM detectors using rectification, a threshold also exists.

The phase-lock loop may be visualized as a tracking filter which tracks the frequency of the radio carrier, thereby reducing the effective radio frequency noise bandwidth. This reduces the required threshold signal strength. This method is illustrated

in the block diagram on page 37 in which the input is a frequency modulated radio carrier. The phase of the input carrier is compared with the output phase of the local FM oscillator and the difference is used as an error signal to correct the frequency of the local oscillator. Since the error signal can be filtered to remove some of the noise (it must pass frequencies including the important components of the information signal modulating the radio carrier), the net effect is a reduction in threshold signal required to realize the FM improvement from the carrier. This is illustrated by the dotted line in the graph on page 37. The demodulated output can be obtained at point *A* in the block diagram or the output at *B* can be demodulated by a discriminator. In one application, a reduction in threshold in an FM telemetry system carrier by as much as 20 db has been reported. This amounts to two orders of magnitude in radio frequency power.

Reduces Carrier Signal Strength

Reduction in required threshold power does not improve the output signal-to-noise ratio when above threshold; it merely reduces the carrier signal strength at which the output signal-to-noise ratio rapidly deteriorates, as indicated in the graph. In most measurement applications, a minimum acceptable output signal-to-noise ratio is required to reach the test objectives or other objectives.

If, in a particular design, the value of the output signal-to-noise ratio at carrier threshold falls below the required output signal-to-noise ratio, then the "effective threshold" for that measurement is not the carrier threshold, but a higher value of carrier signal strength, which may be determined from a graph such as that on page 37. Assuming that the phase-lock device functions equally well for wider frequency deviations, the signal-to-noise ratio in the output can be increased to the desired level by using sufficiently large frequency deviations of the carrier. This uses up more bandwidth and will be commented on below.

In many telemetering applications, many channels of information are multiplexed onto a single carrier, such as FM sub-carriers on an FM carrier, to give an FM-FM system. In this case, the threshold of the sub-carrier must also be considered and, to realize the advantages of a phase-lock receiver on the carrier, it may also be necessary to use phase lock on the sub-carriers with "loops in loops." (See F. W. Lehan, loc. cit.) The sub-carriers may be further multiplexed, such as by time division, to give PAM-FM-FM or PDM-FM-FM or, by frequency division, to give FM-FM-FM, etc. If this further multiplex has a threshold effect, as does PDM or FM, then this must be taken into account.

Reducing Number of Channels

Even with existing telemetering systems, and in fact with any system, a great deal can be gained by carefully planning the measurements themselves to reduce the number of channels of information which must be transmitted and the precision required. This can be accomplished by applying theoretical or experimental knowledge of the behavior of the system upon which the measurements are taken and by performing operations, wherever possible before transmission, on the data which reduce the information content to be transmitted.

An example of the latter would be a situation in which the desired information is really the difference between two measurements. If the difference is taken before transmission, rather than after reception, the information capacity required of the telemeter is reduced. Another example is the case where the wide-band time history from a vibration pickup is transmitted over a channel. Subsequently, the only use of this data is to obtain its power spectrum from a spectrum analyzer.

Of course, the power spectrum contains orders of magnitude less information than the time history signal, which itself has an information rate much less than that of the wideband channel necessary if no special coding is used. If the spectrum analyzer is included in the telemeter transmitter with only the spectrum information being transmitted, the saving in channel information capacity is very great. Such approaches might be called "airborne data reduction."

To summarize, if the most optimistic figures are taken—20 db for improvement in receiver noise performance, 20 db for improved modulation and demodulation procedure, and 50 db for directional transmitting antennas—a total gain of 90 db would be achieved over current telemetering practice. This is equivalent to an increase of range of 4.5 orders of magnitude.

For example, if an RF bandwidth of 500 kc, with 10 watts transmitted power, an omnidirectional transmitting antenna, a 60-ft-diam receiving dish, a 6 db noise figure for the receiver, and a 10 db threshold, are taken as representative of best current telemetry practice, the 90 db improvement would indicate an over-all range

of about 10^8 miles in free space. Further increases in range may be obtained by reducing the RF bandwidth, in which case the range scales inversely as the square root of the bandwidth.

Frequency Allocation

Increasing use of radar, radio, TV and other bandwidth consuming devices is seriously crowding technically feasible frequency allocations in general, and radio telemetry allocations in particular. The history of the frequency bands available for radio telemetry shows a continued pressure toward higher frequencies. For example, during World War II and just after, the region around 70 mc was available. Now the lowest frequency band assigned to telemetry is 217–220 mc, with the 220–240 mc region available on a limited basis. There is increasing pressure by early warning radar and navigational devices to force telemetry frequencies to the 2200–2300 mc band.

The characteristics of the radio link are strongly dependent on the carrier frequency. The efficiency of the power stage of the radio transmitter with currently available tubes drops off with increasing frequency, particularly above 100 mc. Also, airborne components, including stabilized cavities and plumbing for the 2000 mc region, tend to be heavier than corresponding articles for use in regions around 100 mc and lower.

If highly directional transmitting antennas are required to beam the power at the receiving antenna, this usually can be accomplished more easily at the shorter wave lengths, since the linear dimension of the antenna for given directivity is proportional to the wave length. If nondirectional transmitting antenna characteristics are required, this usually can be accomplished more easily at longer wave lengths, particularly if it is possible to resonate the structure, or parts thereof.

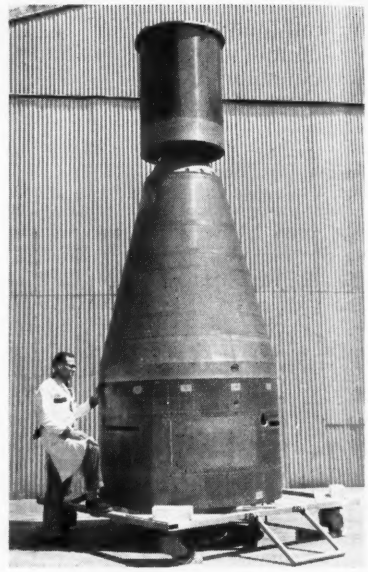
At the receiving end, the effective antenna area for a given directivity is proportional to the square of the wave length. The noise added by the receiver itself depends on the operating frequency. With current receiver practice, at 220 mc, receiver-added noise is 3 to 6 db less than at 2200 mc, but, as noted earlier, future prospects are for considerable improvement, particularly in the microwave region.

For those applications requiring long-range transmission where it is impractical to beam the transmitted power at the receiving station and where extremely large receiving antenna dishes are impractical because of physical size and narrow beam widths, it is currently desirable to use transmitting frequencies in the 10 to several hundred mc region, where relatively simple and not-too-directive receiving antennas with large effective area can be used and where efficient and lightweight airborne RF equipment is available.

For shorter-range missiles, where received signal strength is less of a problem, the shorter wave length region, such as 2200–2300 mc, is feasible, although it presents more difficult problems in RF circuit design, construction and operation, and the equipment is thus somewhat more complicated and expensive. If it is feasible to use highly directive transmitting antennas of limited size, microwaves can be used effectively.

The present U.S. satellite transmitting frequency is 108 mc. This is in the FM broadcast band and is operating there apparently under the condition that it will not interfere with services already assigned to this band. The Russian satellite frequencies have been 20 and 40 mc and, at least as far as U.S. regulations are concerned, are under the same conditions. Since the satellite effort is now receiving a great deal of public attention, it is in a somewhat more favorable position for obtaining the use of optimum frequency bands than the more routine, secret and less publicized telemetry activities connected with military hardware development.

Also, at least at present, RF hard-



All Nose

Technician inspects special nose section for first stage of Army Jupiter-C. Spin launcher atop nose cone spins off second and third stages of giant missile. It was made at Reynolds Metals Co. missile plant, at Sheffield, Ala.

ware for satellites is less standardized and expensive, so the risk of using wave lengths which are only temporarily available is somewhat less than in the case of military test ranges and users, where there is a very large investment in more standardized equipment.

As mentioned above in connection with the discussion of the phase-lock loop, improvement due to the phase-lock principle is in reduction of threshold with no improvement in the above threshold output signal-to-noise ratio. If the output signal-to-noise ratio at threshold is less than the minimum acceptable, then wider band modulation must be used. From this point of view, it may be said that phase lock permits the use of a wider band modulation without the corresponding larger threshold penalty characteristic of conventional practice. But this further complicates the problem of frequency utilization and assignment!

Reliability

Reliability is such a very large subject that only several small facets can be mentioned here. For purposes of discussion, reliability of telemetry apparatus may be defined as the probability that it will function in the desired manner over the required period of time and subject to the environment encountered. By careful analysis or by testing at extremes, it is usually possible to identify the least reliable components of a system and to concentrate on their testing and development. However, to give the reliability a number, a sample of statistically significant size must be tested under the prescribed conditions.

In general, this requires a considerable amount of equipment to simulate the environment and a large number of tests on a large number of units. This is an expensive proposition, but the expense must be compared to the expense of conducting a development testing program in which the telemetry equipment is used. It appears to the authors, and others, that a quantitative knowledge of reliability is essential, so that such things as trade-offs between complexity, number of channels of information, space, weight, power, etc., and reliability, can be made by those planning the tests.

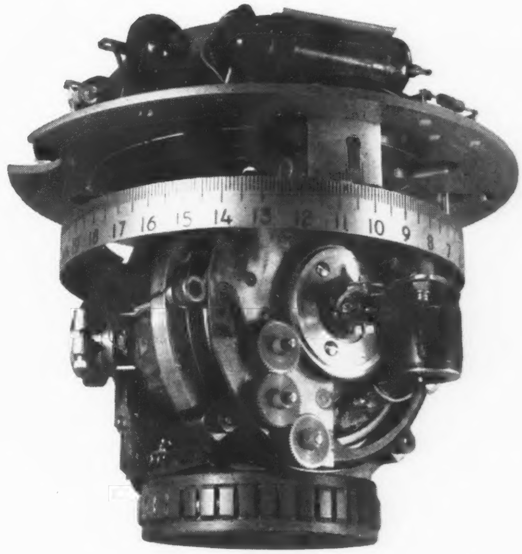
In testing large missiles and aircraft of high unit cost, it has been deemed necessary to make hundreds of radio telemetering measurements in each flight, in addition to the land-line measurements which are made while the missile (and sometimes the aircraft) is on the ground. Calibration of the instruments to make such a large number of measurements is a very large task. In many cases, it has been considered necessary to perform end-to-end calibration on many measurements, and it has often been controversial as to whether all channels should be calibrated end-to-end.

In terms of the size of the task and its requirements in skilled manpower and in dovetailing into other test range activities, it would represent a considerable step forward if the instruments and associated equipment could be made sufficiently stable that laboratory calibration before installation could be relied upon without further calibration and checking. Of course, a factory checkout of the missile or aircraft wiring and telemeter installation must be made to see that things are properly connected up and functioning.

To arrive at such a favorable situation, considerable development and testing of telemetry gear, particularly end instruments, are required. Such a program would involve many agencies and organizations and would require careful planning and financing.

ND FACTS

Symbol of a reputation for integrity, quality and service—for advanced creative engineering achieved by New Departure in over half a century of precision ball bearing manufacture.

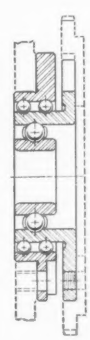


Sperry C-11 Gyrosyn® Compass with Rotorace bearings will give ultra-precise navigation to the new jetliners.

1200% GAIN IN GYRO ACCURACY WITH NEW DEPARTURE BALL BEARINGS!

A major advance in gyroscope construction by Sperry Gyroscope Company results in a remarkable reduction of random drift rate. Involving a special design of gimbal bearings, rates of 2 to 3 deg. per hour, recently considered very good, are now cut to as little as 0.25 deg. per hour with still lower rates in sight.

New Departure created the special manufacturing techniques for the high-precision production of unique ball bearings—another indication of New Departure's ability to meet exacting instrument bearing requirements thru wide engineering experience and precision manufacturing facilities.



The Sperry Rotorace (TM) Gyroscope employs two bearings, one concentric within the other. One outer race is fixed to the gimbal frame, while the other carries a light gear by which it is rotated in periodically alternating directions.

In addition to reducing random drift due to any microscopic irregularities or possible foreign particles, rotation of the bearing race also reduces bearing static or break-away friction.

1908–1958

GM

FORWARD FROM FIFTY

NEW DEPARTURE

DIVISION OF GENERAL MOTORS, BRISTOL, CONN.

NOTHING ROLLS LIKE A BALL

Electronic Materials Frontier

(CONTINUED FROM PAGE 27)

multiplicity are, in general, somewhat more difficult to solve than are those of functional multiplicity. The general situation can be vastly simplified if efforts are made to extend, for example, phase diagram or diffusion studies. A few data taken at points somewhat beyond the scope of the immediate problem can put some sort of handle upon multi-component systems which otherwise must remain *terra incognita*.

Microanalogy—An Approach

Thus far, the burden of the demand for materials has been placed upon the materials technologist at work with the classical cut-and-dried approach. It has become obvious that this will not solve all of our problems. There are not enough competent workers, laboratory facilities or years at our disposal. There is a more general and economical approach, which may be termed microanalogy. It amounts to the application of the physics of materials and their defects to practical problems.

The first aspect of microanalogy is the use of available data on the chemical or physical properties of essentially undisturbed materials in the problem of material specification. This is in part the more or less intuitive reasoning process by which the knowledgeable materials technologist selects three or four out of an apparently infinite number of materials as possibilities for a given program. This approach tends to omit from consideration the relative densities of crystal defects and their effect upon the properties of materials.

A striking example is the effect on the properties of germanium of an excess density of the lattice defect known as the vacant site. Gross changes in electrical conductivity and charge carrier lifetime result from the introduction of only a few tens, or at most hundreds, of parts per billion of vacancies. Improper heat treatment of a germanium transistor in fabrication can introduce this seemingly trivial number of defects and reduce the product to scrap.

Almost all solid materials appear to contain similar, if not quantitatively identical, structural defects, such as the vacant lattice sites previously mentioned. Impurity atoms in normal sites or in interstices of the lattice are typical defects. Atoms of the pure material may also be found in lattice interstices.

Dislocations are defects which arise from an improper mating of the atomic planes in a crystal. One type of dislocation is easily visualized as resulting from the insertion into the lattice of an additional half-plane of atoms. While the average number of such dislocation lines intersecting the surface of a metal may be of the order of one per 10,000,000 surface atoms, the mechanical properties of the metal are almost completely controlled by their presence. For instance, the ultimate strength of a metal may be lower by a factor of 10 relative to the same material in the dislocation-free state.

One striking example will serve to demonstrate the value of microanalogy in approaching a problem in electronic materials technology. Approximately 10 years ago, the point-contact germanium transistor was announced. Within a few years, germanium material production was on a sound basis, and problems of electrical reproducibility and production capacity had been solved.

As requirements for higher-temperature transistors were generated, the industry turned toward silicon as the next step. The first few years of this work were singularly unrewarding in terms of finished, salable components, but funds were unhesitatingly provided by government and industry. Silicon material of sufficiently high quality for transistors was extremely difficult to obtain and, once in hand, was nearly intractable. Had there not been strong confidence in the validity of the microscopic analogy of silicon to germanium, the development program would probably have been sharply curtailed.

Actually, however, the successful development of silicon transistors was due in large measure to a recognition of the fact that the influences of defects upon silicon and germanium, while similar, are quantitatively different. Once the intuition of the materials technologist was coupled with the sophistication of physicists and chemists, the problem could be solved.

Microanalogy, then, requires at the outset a basic understanding of the properties of materials. This must include not only the gross properties but also the more subtle influences of defects. Furthermore, information concerning representative compounds and solid solutions must be available. By using survey techniques, the materials technologist is then much more likely to be able to choose a material to solve a given problem.

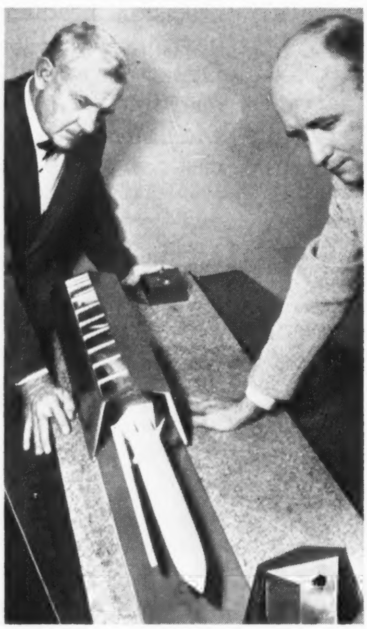
The task of the materials technologist is becoming a more difficult one despite the fact that theoretical and experimental data are being generated at an increasing rate. Operating temperature ranges, for example, are lengthening both up and down the scale. We are running beyond existing data and, in many cases, beyond the capabilities of laboratory test facilities. It is becoming apparent that entirely different requirements are indicated by the new environment. The demands of the future will also introduce new problems which may have to be attacked as thoroughly and as expensively as was nuclear radiation damage.

Not Needed for Each New Job

It is clear that new materials are not required for each new job. Knowledge of the properties of existing materials will often provide satisfactory solutions. In some instances, new materials have been developed to the point of mass production only to become obsolete and be replaced by other materials long available but insufficiently characterized. In other cases, new materials are vitally essential. These must not only be developed but studied intensively.

Progress will be assured by maintaining a balance between the development of new materials and the continued exploitation of old.

Do-It-Yourself Shelter for Thor



Model of movable, demountable shelter for Thor missile is studied by architects at Southwest Research Institute, which designed the hangar. The unit can withstand extreme heat, cold and winds up to 120 mph. Douglas is building prototypes.

government contract awards

GE Lets $4.2 Million Pact For Atlas Electronic Systems

General Electric's Heavy Military Electronic Equipment Dept. has let a $4.2 million AF contract to National Company, Mass., for design, development and production of complex electronic systems for the Atlas ICBM.

$100 Million Super-Radar System Contract Let to GE

A subcontract to exceed $100,000,000 has been awarded to General Electric's Heavy Military Electronic Equipment Dept. by the Radio Corporation of America for the design, development, production, testing and placing in operation the world's largest known radar system. This super-radar system will play a major role in the Air Force's Ballistic Missile Early Warning System.

Convair Gets Tartar Contract

Convair has been awarded an $8 million Navy contract for pilot production of Tartar guided missiles.

Navy Missile Launcher Contracts

The Navy has awarded $14,182,000 and $6,350,000 contracts, respectively, for missile launchers to two Minneapolis firms, Northern Ordnance Co. and General Mills.

$140 Million AF R&D Contract Signed by American Bosch Arma

American Bosch Arma Corp. has signed a $140.3 million AF R&D contract to provide inertial guidance systems for the Titan ICBM. The sum represents a definitizing of costs for R&D work on the guidance system begun by Arma in 1955. About $51 million of the total sum already has been expended.

Servo Gets AF Advanced IR Recon-System Contract

An AF development contract for five advanced infrared reconnaissance systems in the amount of $583,820 has been awarded to Servo Corp. of America.

Gyros for Bullpup

The Martin Co. has awarded a $489,000 contract to Telecomputing Corp. for roll-controlled gyros for the Navy's Bullpup missile.

Missile Support Contract

The Army has awarded a $5 million contract to Consolidated Diesel Electric Corp.'s Power Equipment Div. for several hundred 45 kw, 400-cycle power generators for use in missile pre-launching control and communications.

Talos and Terrier Components

The Navy has awarded Sperry Gyroscope Co. three contracts totaling approximately $63 million for production of major components of Talos and Terrier missile.

More Titan Work for Hallamore

Hallamore Electronics has received a $3 million addition to its contract for instrumentation and field test equipment for the Titan ICBM from the Denver Div. of Martin Co., bringing total amount of work being performed by Hallamore on the project to $12 million.

SYNOPSIS OF AWARDS

The following synopsis of government contract awards lists formerly advertised and negotiated unclassified contracts in excess of $25,000 for each Air Force, Army and Navy contracting office:

AIR FORCE

AF Flight Test Center, ARDC, USAF, Edwards AFB, Calif.

Construction of X-15 test facility, $318,924, **P. J. Walker Co.**, 3900 Whiteside St., Los Angeles 63, Calif.

Commander, Hq AMC, Wright-Patterson AFB, Ohio.

Services for test time at AF Marquardt Jet Laboratory, Van Nuys, Calif., $198,077, **Marquardt Aircraft Co.**, 16555 Saticoy St., Van Nuys, Calif.

Production of motion picture, "Logistic Support of Missiles," $28,920, **Atlas Film Corp.**, 111 So. Blvd., Oak Park, Ill.

Type MD-1 liquid oxygen tank semitrailer, maintenance data and engineering data, $406,226, **Cambridge Corp.**, 2 Industrial Park, Lowell, Mass.

Interconnecting box, missile auxiliary, $322,565, **Radio Corp. of America**, Defense Electronic Products Div., Front and Cooper Sts., Camden, N. J.

Hq AF Cambridge Research Center, ARDC, USAF, Laurence G. Hanscom Field, Bedford, Mass.

Rocket, Aerobee-Hi sounding model, rocket booster, spare parts and replacements, $387,730, **Aerojet-General Corp.**, 6352 No. Irwindale Ave., Azusa, Calif.

Hq AF Missile Test Center, ARDC, USAF, Patrick AFB, Fla.

Rocket propellant, $37,873, **Westvaco Chlor-Alkali Div. of Food Machinery and Chemical Corp.**, 161 E. 42 St., New York, N.Y.

Hq AF Office of Scientific Research, ARDC, Washington 25, D.C.

Continuation of research on analytical study of high frequency oscillatory combustion and of scaling up of rockets, $50,000, **Polytechnic Institute of Brooklyn**, 99 Livingston St., Brooklyn 1, N.Y.

Research on low temperature plasma jet, $54,015, **Aerochem Research Laboratories, Inc.**, P.O. Box 12, Princeton, N.J.

Research on formation of free-radical solids using beam techniques, $57,753, **General Atomic Div.**, P.O. Box 608, San Diego, Calif.

Reports concerning studies in heat transfer from gases to cylinders and nozzles, $653,317, **General Electric Co.**, Cincinnati 15, Ohio.

Hq San Antonio Air Materiel Area, USAF, Kelly AFB, Tex.

Repair and overhaul of J-69-T9 turbojet engines, $441,381, **Continental Aviation & Engineering Corp.**, 12700 Kercheval Ave., Detroit, Mich.

ARMY

Corps of Engineers, Office of the District Engineer, U.S. Army Engineer Dist., Tullahoma, Tenn.

Design, manufacture and deliver compressor drive systems for the second increment of the plenum evacuation system of propulsion wind tunnel, Arnold Engineering Development Center, Tullahoma, Tenn., $4,983,654, **Allis-Chalmers Mfg. Co.**, Milwaukee, Wis.

Construction of air inlet filter and supersonic control buildings, cart area superstructure of supersonic circuit of propulsion wind tunnel, Arnold Engineering Development Center, Tullahoma, Tenn., $154,460, **Pittsburgh-Des Moines Steel Co.**, Neville Island, Pittsburgh, Pa. Subcontracts for concrete work and excavation open.

Los Angeles Ordnance Dist., U.S. Army, 55 So. Grand Ave., Pasadena, Calif.

Rocket engines, $750,000, **North American Aviation, Inc.**, 6633 Canoga Ave., Canoga Park, Calif.

Replenishment repair parts for Corporal, $200,424, **Gilfillan Bros. Inc.**, 1815 Venice Blvd., Los Angeles, Calif.

Repair parts for Nike, $131,092, **Douglas Aircraft Co. Inc.**, 3000 Ocean Park Blvd., Santa Monica, Calif.

Engineering services for Corporal, $1,078,266, **Gilfillan Bros. Inc.**, 1815 Venice Blvd., Los Angeles, Calif.

Engineering research and development related to guided missiles, rockets, and

for wind tunnel operation, $22,771,492, **California Institute of Technology,** 1201 E. California St., Pasadena, Calif.

Rocket engines, $633,000, **North American Aviation, Inc.,** 6633 Canoga Ave., Canoga Park, Calif.

Target drones, $165,694, **Radioplane Co.,** 8000 Woodley Ave., Van Nuys, Calif.

Rocket engines, $370,000, **North American Aviation, Inc.,** 6633 Canoga Ave., Canoga Park, Calif.

Prototype models, $34,835, **Topp Ind., Inc.,** 5255 West 102 St., Los Angeles, Calif.

Repair parts for Nike, $55,861, **Douglas Aircraft Co., Inc.,** 3000 Ocean Park Blvd., Santa Monica, Calif.

Testing equipment, $283,192, **Telecomputing Corp.,** 12838 Saticoy St., No. Hollywood, Calif.

Warhead testers, $1,565,765, **Telecomputing Corp.,** 12838 Saticoy St., No. Hollywood, Calif.

Furnishing and delivering of depot replenishment repair parts for Corporal, $46,080, **Gilfillan Bros. Inc.,** 1815 Venice Blvd., Los Angeles, 6, Calif.

Digital computer, $256,703, **North American Aviation,** 9150 E. Imperial Highway, Downey, Calif.

Warhead tester, $496,358, **Preshaw & Thompson, Inc.,** 14576 Oxnard, Van Nuys, Calif.

Guided missile, surface-to-surface, $28,603, **Firestone Tire & Rubber Co.,** 2525 Firestone Blvd., Los Angeles 54, Calif.

Redstone Arsenal, U.S. Army, Huntsville, Ala.

Continuation of research and development of fabrication techniques for the application of high-strength, lightweight materials in large size rocket engine cases, $194,996, **Thiokol Chemical Corp.,** Trenton, N.J.

Additional costs to perform engineering evaluation tests necessary to complete development of improved two-level thrust system, $74,944, **Thiokol Chemical Corp.,** Trenton, N.J.

NAVY

Dept. of the Navy, Bureau of Aeronautics, Washington 25, D.C.

Materials and services necessary to increase the power capacity of the rocket test area, $225,000, **Reaction Motors, Inc.,** Denville, N.J.

Materials and services necessary to maintain plants for production of military aircraft, missiles and components, $370,000, **Douglas Aircraft Co., Inc.,** 3000 Ocean Park Blvd., Santa Monica, Calif.

Navy Dept., Bureau of Ordnance, Washington, D.C.

Provide facilities for production of Polaris launching system, $132,000, **Westinghouse Electric Corp.,** Washington 6, D.C.

Engineering necessary to integrate components of the Terrier land weapon system for the preparation of an OP, $107,155, **Vitro Laboratories,** Div. of Vitro Corp. of America, Silver Spring, Md.

Guidance by Infrared

(CONTINUED FROM PAGE 35)

fog are made up of particles which are large in comparison to the IR wave length. Thus attenuation of infrared through clouds is substantially as great as is the case for visible radiation.

The infrared designer has a certain degree of flexibility in the choice of components and system designs for the missile tracker. Available infrared detectors of sensitivity and speed of response adequate for missile trackers fall into two categories, lead sulfide and the intermediate wave length cutoff photoconductors.

In the spectral region between the visible and 3 microns, lead sulfide detectors have encountered no competition, and high sensitivity is obtainable in this wave length region by detectors which are small and rugged. Lead sulfide detectors are very effective against tailpipe radiation from jet aircraft targets, as well as water vapor emission from the plume. Under conditions of attack from directions where tailpipe radiation is not visible, a higher efficiency of detection can be obtained by using detectors which are sensitive to carbon dioxide radiation between 4.2 and 4.5 microns. Several detectors are under development and in preliminary production which are sensitive in this spectral region.

Characteristic of the most sensitive of these detectors, such as lead selenide and lead telluride, is a requirement for cooling the element to temperatures in the vicinity of liquid nitrogen. This requirement poses an additional design and logistics problem. Although the proportion of the emitted plume radiation in the 4.2 to 4.5 region is large, compared to that available at the shorter wave length, sensitivity of the detector to the longer wave lengths is considerably less than that of lead sulfide. As a result, the designer must evaluate the over-all design situation before deciding on which detector to use.

The nature of infrared radiation is such that optical techniques can be used to collect and focus the radiation. Optical system designs, employing lenses, mirrors or prisms, are very similar to those used in the visible spectrum. However, many materials transparent in the visible have little or no transmission in the IR region of interest, hence become unusable.

The first surface mirrors are identical in the IR optical system with those incorporated in visible systems designs. In the lead sulfide sensitive region, most of the common glasses are fair transmitters. If maximum utilization of lead sulfide spectral sensitivity is desired, it is necessary to use either special glasses or other materials, such as quartz. As transmission to wave lengths farther into the infrared spectrum is desired, the number of available optical materials becomes smaller and smaller. Special materials such as arsenic trisulfide, crystalline germanium and silicon have come into common use for these optical systems.

The ultimate limitation in the imaging capability of infrared optical systems is established by the wave length of the radiation focused. In comparison to the visible, this limitation is greater by a factor of five to 10. However, the limiting angular resolving power of IR systems is still more than adequate for most military applications.

Perhaps the most severe performance limitation of infrared tracking systems is that set by the level of radiation from the sky background against which the target is observed. Under nighttime conditions, lead sulfide systems generally perform up to the limit of their basic capability to detect target radiation. Sensitivity under these conditions in a well-designed system will be limited by the noise level of the detector itself. Against daytime sky backgrounds, particularly brightly illuminated clouds, simple lead sulfide devices will be easily distracted by the reflected solar radiation.

The sensitivity, then, is limited by the level of response of the system to background radiation. Various design techniques have been employed which take advantage of the differences in physical characteristics between the target and background. The sun and bright daytime clouds exhibit a spectral distribution which peaks in the visible and falls off rapidly in the infrared region. By taking advantage of the fact that target radiation peaks at longer wave lengths, some degree of discrimination can be obtained by the proper choice of optical filters which severely attenuate background radiation while allowing most of the target radiation to pass. A typical filter used in lead sulfide systems, for example, is made of a plate of crystalline germanium which blocks out radiation of wave lengths shorter than 1.8 microns while passing the longer wave lengths. Different detectors and types of targets call for variations in the choice of filter characteristics.

Aids Discrimination

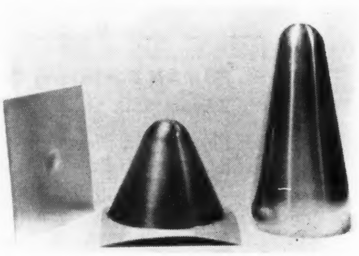
The general fact that the distant target appears to the tracker as a point source of radiation, while clouds and sky spread over large, solid angles, provides another means of discrimination which may be employed in design. At the proper place in the optical system, a reticle consisting of alternate transmitting and opaque bars may be located. The scanning operation is such that the image of the point target is efficiently modulated, while radiation from the background is either incompletely modulated or unmodulated.

Further gain in the discrimination operation can be obtained through selection of the optimum means of electronically processing a signal from the detector. By employing circuit techniques, many of which have been adapted from similar radar processing circuits, a high degree of effectiveness can result. Current development activity in infrared guided missiles, as well as of other IR detection devices, is devoted largely to the application of combinations of optical filtering and space filtering, together with signal processing, which provide greatest reliability of target detection.

At the present time, infrared is being applied to a variety of missile guidance problems, most of which are highly classified. Recently, two air-to-air missiles which use IR guidance systems have reached operational status, and the fact of their existence has been released to the public. The Sidewinder missile, designed and developed by Naval Ordnance Test Station, China Lake, Calif., employs a lead sulfide detector, and is being applied extensively in the military armament. The Hughes Falcon missile, specifically the GAR-2A, also uses a lead sulfide IR seeker for guidance.

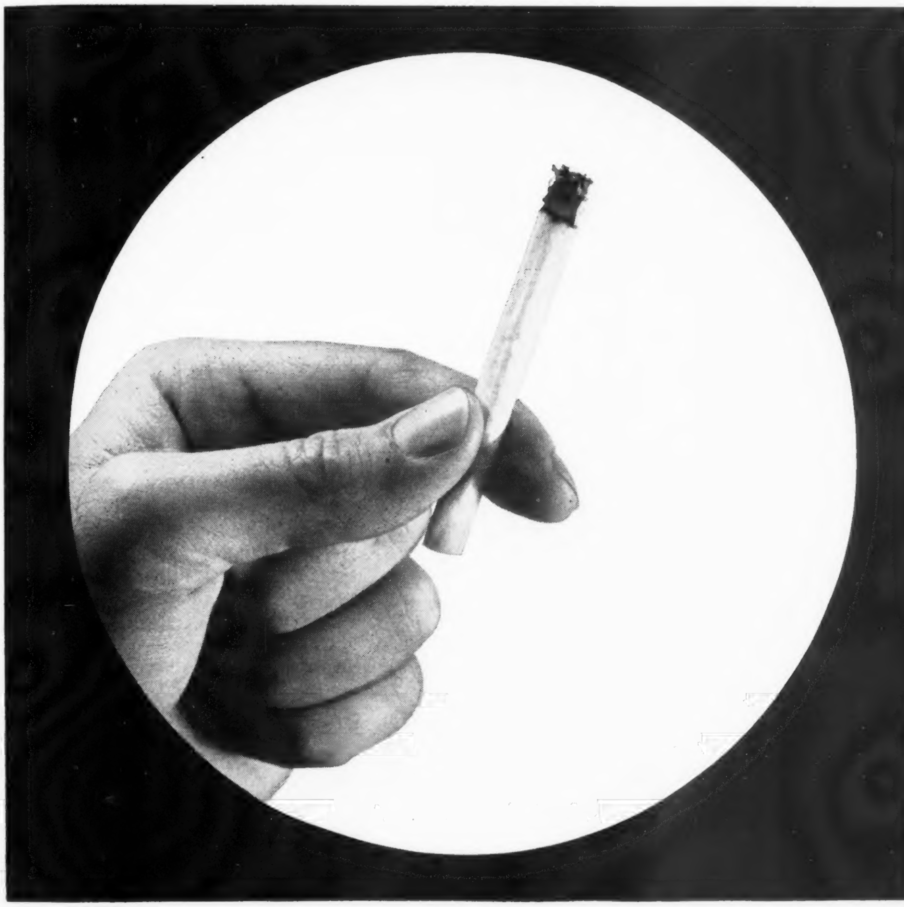
It is expected that, with the evolution of design techniques and their reduction to practice, missile guidance by infrared will find increasing application not only in the air-to-air category but also as the homing guidance phase of longer-range missiles.

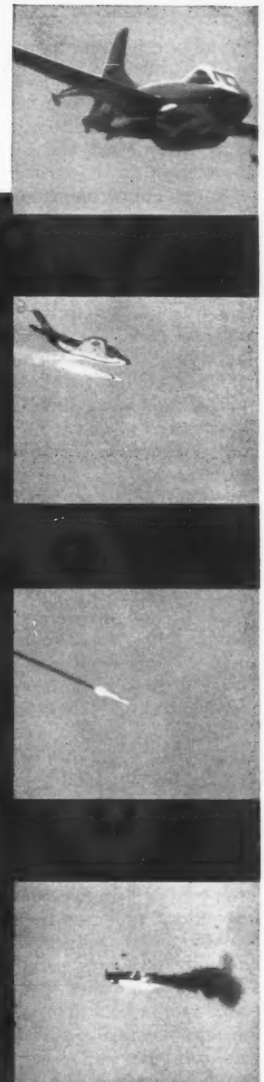
Three Steps Before Space



Three metal forming steps transformed the dimpled stainless steel blank (left) into the Explorer's nose cone. The cone, spun by a new process called Floturn at Lodge & Shipley Co., ranges in thickness from conical walls of .013/.017 in. to .094 in. at middle of blunt nose.

Invitation to **SUDDEN DESTRUCTION**





Defender plane, armed with wing-mounted Sidewinder missiles pursues target . . . Sidewinder is fired . . . guided by infra-red, the missile "homes" on target . . . bringing sudden and inescapable destruction.

...even this tiny glow will actuate the super-sensitive, infra-red controls of the deadly Sidewinder missile.

Sidewinder, streaking through midnight skies on its mission of air-to-air defense, is but one dramatic example of Philco leadership in advanced infra-red technology. Conceived by the Naval Ordnance Test Station at China Lake . . . developed by Navy and Philco scientists . . . engineered and produced by Philco, the Sidewinder is a result of close weapons systems development coordination.

In the forefront of infra-red research and solid state physics, Philco is pioneering detectors which cover the entire IR spectrum including; proximity warning indicators, advanced photographic (black light) techniques, high precision industrial IR electronics, search gear and fire warning systems. Here is dramatic proof of Philco leadership in technology, capacity and flexibility. In the Wonder-World of advanced electronics . . . *look ahead . . . and you'll choose Philco.*

At Philco, opportunities are unlimited in electronics and mechanical research and engineering.

PHILCO®

GOVERNMENT & INDUSTRIAL DIVISION

4702 Wissahickon Ave.
Philadelphia 44, Pa.

Radio Guidance Techniques

(CONTINUED FROM PAGE 32)

the moon by listening for 10 seconds, we would have to listen for 18 days to detect it on Mars, and 5×10^{10} years to detect it on the nearest star.

Another approach is to use relay stations. Again using the moon-located beacon as a standard, 23 relays would suffice to Mars and 23,000 to the nearest star. (That is assuming no degradation of the signal due to relaying—a situation closely approximated by certain digital systems.) Consider the interesting problem of keeping all the relay stations on a straight line!

Admittedly, we have considered the radio measurement problem in a much more extreme case than usual. But, as stated earlier, we are looking more into the future than into the past.

Command by Radio

Most of the concepts discussed in connection with radio probing, of course, apply to radio commands. For precisely the same reason that it is wasteful to remeasure quantities already known, it is wasteful to send the missile information it already has. It is obviously absurd to send information that the missile doesn't need.

The interference problem, malicious or otherwise, is quite similar, but somewhat more tractable in the command case than in the measurement case. Radio propagation effects are less serious, precision timing is seldom required and occasional drop-outs generally have a less serious effect. In addition, commands can usually be coded more easily than measurements.

Codes have classically been used as confusion devices. More recently, largely as a result of Clyde Shannon's work, codes have been recognized as an effective interference suppressant. Used in this way, it is the function of the coding process to convert a quantity (say, the number 23) into a form best suited for transmission over a radio link. For example, assume that the best form is taken to be the shortest, and that transmission can consist of either 1's or 0's. Then, the various forms might be: 0111111111-11111111111110 (twenty-three 1's with a 0 for a break), 0101011011011-0001010101101100 (Morse code with three 0's for a break), or 01011100 (binary with three 0's for a break).

In this example, the binary is evidently the best. Morse would have fared better against single 1's if the number had been 23,000, rather than 23. Codes in combination with some built-in common sense system can be extremely effective in rejecting enemy efforts at simulation. This is indicated in the figure on page 32. For example, suppose we wish to send a steadily increasing function: 1, 2, 3, 4, 5. Choose a code series such as 253, 648, 932, 870, 555 to represent the numbers in sequence. Then, suppose the enemy interferes such that we receive 253, 648, 932, 234, 555 which "decodes" to 1, 2, 3, 412, 5. Discarding the 412 and replacing it with the proper "4" is then simple.

The most difficult problem in radio command is not how to send the commands but what commands to send. We have been duly warned that irrevelant commands are wasteful. We might anticipate that certain erroneous commands, such as "destroy yourself" or "discard the first stage," could be disastrous. But in addition, the missile never responds the same way twice to the same command. It can't! Missiles under propulsion are constantly changing their mass, their center of gravity, their aerodynamic conditions (particularly ballistic missiles), and their ability to respond.

Time Constants Vary

At one time in flight, response might be virtually instantaneous; at another, sluggish. "Time constants," as electronics engineers call them, can vary by a factor of several hundred. To compound the problem, a given trajectory change (for example, an increase of 1 fps in side velocity) produces different effects with regard to hitting the target, depending on when the change is applied. This is shown on page 32. The example is often quoted of the seriousness of a very small error near launch on the likelihood of landing on the moon. Correcting by the same amount later on is next to worthless. An error of $^1/_{100}$ of 1 per cent in velocity can mean missing the moon altogether.

Once again, some very elegant theory had to be developed. In this case, the theory involved both optimization of time-variant linear systems and perturbation calculus. Particularly unnerving to designers used to thinking about more conventional devices were the changed definitions of stability. Many of the old criteria were now wrong. In some applications, systems were deliberately designed that would have been "unstable" by previous rules. (One consequence appears to be that, when a missile goes wrong, it really goes wrong.)

The difficulty in deciding what command to send is a matter of degree. In the simpler, shorter-range missiles, the commands may be only the displacement of the missile from the desired course. In the complex, earth-spanning missiles, the commands incorporate not only displacement, but also velocity functions carefully chosen to mate with the inertial measurement capability of the missile.

Sending commands from the base to the missile has one serious disadvantage: The number of missiles which can be handled at a time is limited. For this reason, some radio systems are designed so that the missile computes its own commands on the basis of radio measurements made by itself. The beam rider is a good example. The principal disadvantage, of course, is that the complex computer is now transferred from the base to the missile, where its environment is much more rugged.

There must be an easier way, you say? Unfortunately, there isn't. Electromagnetic waves are the only known way of observing events occurring at a remote location across a vacuum. If the events must be observed, as in the case of an intelligently maneuvering target, there is no choice.

In some applications such as ballistic missiles going from one point on the surface of the earth to another, the radio system is used because its technology is actually simpler than that of the theoretically "sufficient" all-inertial system. As inertial systems become better, radio techniques can be expected to be displaced in this task.

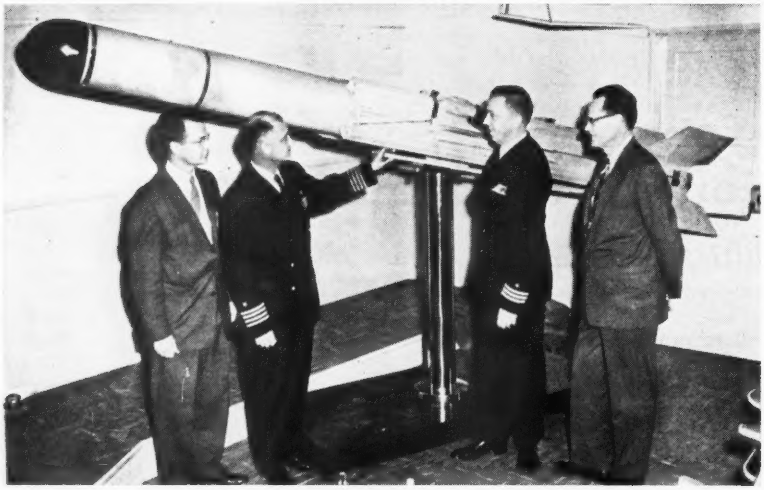
Guidance of space vehicles introduces several new factors. The times of passage become extreme by present day standards. Propulsive accelerations may be minute compared with gravitational and centrifugal accelerations. And, strangely enough, we don't know distances in space—or rather we know distances only to a scale factor. The scale factor is the velocity of light, the only yardstick available in space. Electromagnetic radiation to and from the missile may be the only reliable surveyor's chain for some time to come.

Bigger Role for Woomera; Thor Tests in Offing

CANBERRA, AUSTRALIA—The Woomera Satellite Center will function as control center for planned space studies of the earth's magnetic field. The center is installing a precessional magnetometer, lent to it by the U.S. Naval Research Laboratories, to receive information from magnetometers placed in future U.S. satellites.

Discussions are also under way between the Australian government and the U.S. and England concerning use of Woomera for testing Thor missiles, which may be first step toward U.S. use of Woomera for test firings of other long-range weapons.

—A.R.S.



New Navy Sub-Killer

NOTS personnel inspect the Rat, part rocket, part torpedo. The Navy's new anti-submarine weapon can be fired from existing destroyer 5-in. gun mounts. After firing, its rocket engine and air frame fall away, releasing the 8-ft torpedo, which drops to sea by parachute and seeks out target.

Electronics and the Missile

(CONTINUED FROM PAGE 21)

vations or adjustments during the flight of a missile, the demands on the reliability and stability of the individual components are considerable, even for the accomplishment of successful experimental flights. Unfortunately, we had to learn this the hard way. The importance of complete telemetered information during test flights was also overlooked in early missile programs. Happily, the state of the art today and the sophistication of many of the engineers in the field are such that missile design is now a straightforward and predictable affair.

We now understand system dynamics thoroughly enough to design stable control systems without long, costly, trial-and-error techniques. Computer simulation technology and the understanding of system dynamics have progressed to the point where the dynamic performance of a missile can be predicted with great reliability.

For the first generation of missiles, many components had to be developed from scratch. There were no telemetering systems, no telemetering instruments, no proper autopilots, no adequate gyroscopes, no suitable radars, no suitable control systems, no suitable power supplies, no suitable motors, no suitable vacuum tubes. The existing electronic components which were pressed into service could not endure the extreme environmental conditions to which they were subjected in the guided missile.

In fact, in retrospect it appears that almost every single thing required for missiles had to be developed new for the job. As one might have anticipated, the early components were often inadequate for the jobs they were asked to perform. They were designed in a hurry and often to specifications poorly expressed and inaccurately describing their intended function.

This situation, too, has changed enormously, and today there is available a large variety of components developed specifically for use in missile applications. Capacitors, resistors, transformers, gyros, vacuum tubes and most of the other components which are required are now designed to operate reliably in the extremely difficult missile environment. In addition, component weight and size have also been reduced in a spectacular fashion.

While conventional components have become more reliable, new inventions have also helped. The development of solid state active elements, notably transistors and magnetic amplifiers, has played an important part in enhancing the reliability of our complex systems.

Existing missile systems are unsatisfactory in many ways. Their unreliability has already been mentioned, and malfunction of their electronic elements accounts for a very large share of missile failures, particularly in the defensive guided missile category.

In almost all missiles that are in operation today, adequate maintenance is difficult. Computers, radars and other electronic equipment are not only hard to service after failure, but are often very hard to get in proper adjustment and often even more difficult to keep in proper adjustment. With the increasing complexity of equipment and the rapid turnover of trained technicians being experienced by the services, the inability to keep electronic gear operating is fast becoming a major military problem.

Greater Reliability

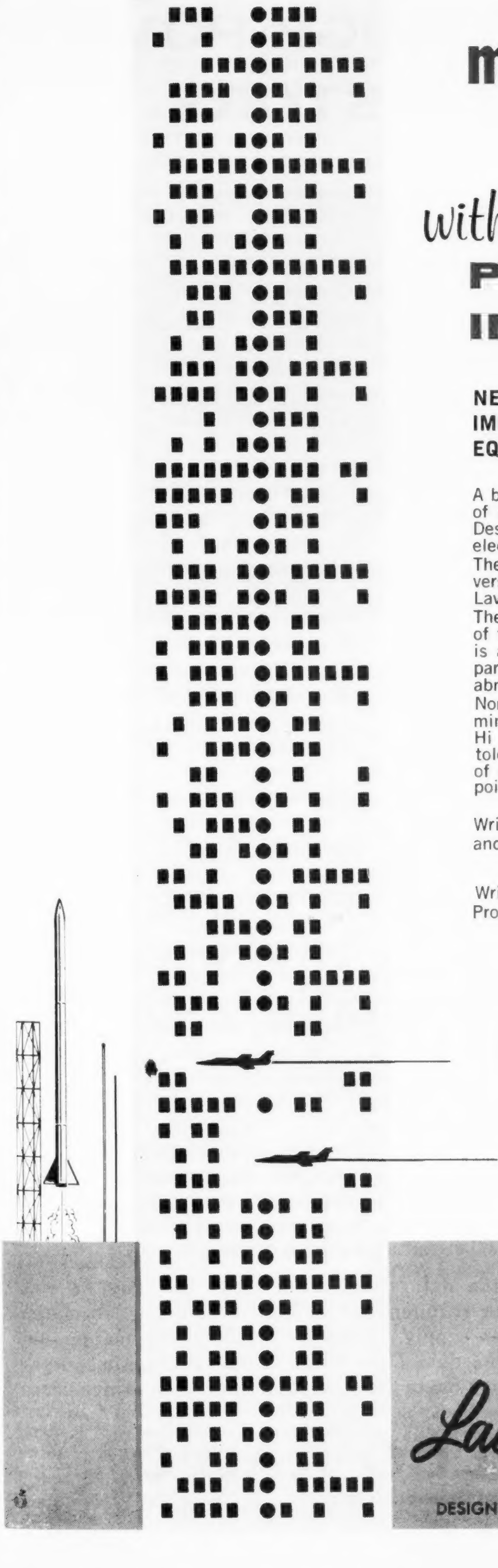
Fortunately, the new components and new techniques now available should make it possible to design and build systems much more reliable than any now in use. Solid state active elements in place of vacuum tubes, redundant circuits in small digital computers, self-checking circuitry and many other aids can result in complex electronic equipment needing little or no maintenance and being so reliable that an in-service failure is a rarity, rather than the normal event.

This state of affairs won't come to pass by itself. It will take more skill, care and imagination to accomplish this goal than was necessary to produce existing missile systems, but the tools are on hand, and if it doesn't occur, the industry will have defaulted on an important opportunity.

Reliability is not the only problem confronting the missile system designer. Modern warfare, Buck Rogers in nature, is demanding ever more from our systems. With faster, higher, smaller aircraft to detect and intercept, radars must have much better performance, intercept-missiles must be faster and more accurate, computers must be faster.

To detect, track and intercept satellites and ballistic missiles, electronic systems having fantastic capabilities are required. To make them, the state of the art must be stretched tenfold. Anti-missile radars require enormous antenna systems and radiate hundreds of kilowatts of average power. Interceptions must be made hundreds of miles from the control point and with only minutes of warning time. Such systems must be alert and working at peak performance all of the time. The accuracy and reliability needed for these tasks challenge the best that we can dream of.

Add to these problems the problems of guidance for ICBM's, satellites and space vehicles, as well as the communication problems they pose, and we have a glimpse of the future role of electronics in the field of astronautics.



Cures

(CONTINUED FROM PAGE 41)

needed a precision differential amplifier with high common mode rejection." So we struggled frantically with the problem for almost a year, and finally succeeded in bringing out a true differential amplifier which will reject almost all noise, hum and spurious information delivered to it.

You would think that by now the problem of precision information and long lines had been solved, but it had not. The instrumentation people overlooked the prime fact of life in instrumentation: *Information is no better than the transducer supplying it.*

A large company in Southern California conducted extensive field tests on the reliability of their transducers under normal operating conditions. In laboratory tests, these transducers were good to better than 0.5 per cent, which would certainly justify the use of a 0.1-per cent amplifier. But the transducers *averaged* only 4 per cent in field use. It's a good guess that 80 per cent of the companies demanding precision data would find similar results in evaluating their field measurements. The fact of the matter is that little or nothing is being done in the most important field—that of the transducer itself.

Let us look for a moment at the great quantities of data being taken and the results of these demands. We will not question the necessity for the large numbers of data points, although we well might.

Dictate Use of Computers

Large quantities of data almost dictate the use of a digital computing machine and an analog converter for data processing. About $3^1/_2$ years ago it was impossible to buy an analog converter. Today there are no fewer than 30 converters with various speeds and precisions on the market. But they all do substantially the same thing—convert an analog signal from a transducer into digital representation for the computing machine.

Because large quantities of data must be acquired in a short time, the converters must operate at high speed. And so today equipment designers must design to a precision of 0.1 per cent or better a machine that will convert analog voltages thousands of times a second. In fact, the demand is now for a machine with a precision of 0.01 of 1 per cent. This equipment in turn leads to the problem of high-speed switches or multiplexers that will operate 0.1 per cent or better, and so on. Likewise, there is today a tremendous struggle to design a FH-type tape recorder with precision up to 0.1 per cent. Driving all this equipment are transducers which in use are good to only about 5 per cent.

The time has come when people who have a good basic knowledge of electricity and a good basic knowledge of system design ought to take existing systems apart bit by bit to find the inconsistencies in them. No system has yet been installed where oversights and inconsistencies in design did not lead to much less than the full potential precision.

Unhappily, the cost is becoming astronomic for these errors.

Based on a paper presented at the ASME-ARS Aviation Conference in Dallas, Tex., March 17-20, 1958.

Pinpoint Navigation System Achieved for Polaris Subs

The Navy took the wraps off its classified Ship's Inertial Navigation System (SINS) project—key to eventual underwater launching of the Polaris missile—and immediately tagged it as "possibly the most radical advance in marine navigation since development of the compass."

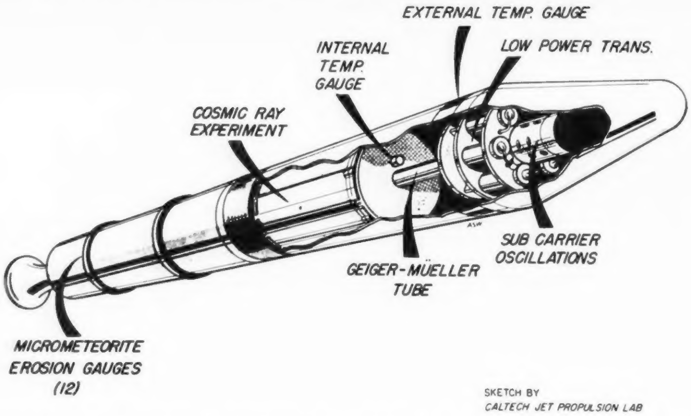
The system, similar in principle to inertial navigation systems, provides ultra-precise navigation without reference to the stars, or use of radio or radar, and exposes nothing that would reveal the position or presence of the submarine. SINS derives information from complex arrangements of gyroscopes and accelerometers and is claimed to be "invulnerable to known . . . enemy countermeasures."

SINS, susceptible to long-term drift, is monitored by occasional reference to celestial fixes. Celestial navigation enables geographical position and direction of North to be determined at any location on the earth's surface, without dependence upon other navigation methods. The system, based on fundamental research carried out by Charles S. Draper of MIT, was further developed for manufacture by Sperry Gyroscope.

AF Developing Million-Lb Thrust Rocket Engine

Air Force Assistant Secretary for R&D, Richard E. Horner, has told the House Armed Services Committee that the AF recently initiated development of a single-chamber rocket engine that would produce one million lb of thrust. He also informed them that studies leading to an engine that could be clustered together to produce more than 1,500,000 lb of thrust were begun in 1954.

Army Fires Explorer III Into Orbit, But Off Course



Payload instrumentation in Explorer III weighs 0.20 lb more than its counterpart Explorer I, 10.83 versus 10.63 lb. Entire satellite weighs 30.8 lb.

On March 26, Explorer III, an almost exact duplicate of its sister-vehicles I and II, was fired into orbit by an Army Jupiter-C rocket. However, because the fourth stage fired a little prematurely and at an angle above the horizontal aimed for, the satellite did not fall into its planned orbit.

The Naval Research Laboratory described the 31-lb satellite's perigee as 110 miles and apogee as 1738 miles. Orbital period was put at 115.7 min. Weight of Explorer I is 30.8 lb. Aboard the Explorer III were instruments for recording data on cosmic rays, meteorite impacts and temperatures. An ingenious feature of the cosmic ray instrumentation was a miniature tape recorder, the size of a pack of cigarettes, which furnishes five times as much information on cosmic ray intensities as Explorer I, and collects data throughout its entire orbit. The tape conveys two hours of information in five seconds as it passes over ground stations.

In place of the turnstile antenna consisting of four whip-like wires used in Explorer I for its high-power radio, the new "moon" used two dipole antennas. This substitution was made when it was discovered that the whip antennas wiggled, causing Explorer I to alter the position it assumed in space when first launched.

Explorer III is transmitting radio signals on the same frequencies, 108.03 and 108 mc, as Explorer I. However, in the former, only the low-power transmitter sends continuous data on external and internal temperatures, one measurement of micrometeorites, and cosmic ray counts. The high-power transmitter sends information only on cosmic rays. In Explorer I, both transmitters telemetered this type of information.

Cryogenic Engineering Forum Scheduled Sept. 3-5

MIT will hold its 1958 Cryogenic Engineering Conference Sept. 3–5. Areas to be covered include cryogenic processes, applications, equipment and properties. Deadline for abstracts (not over 200 words) of papers is June 1.

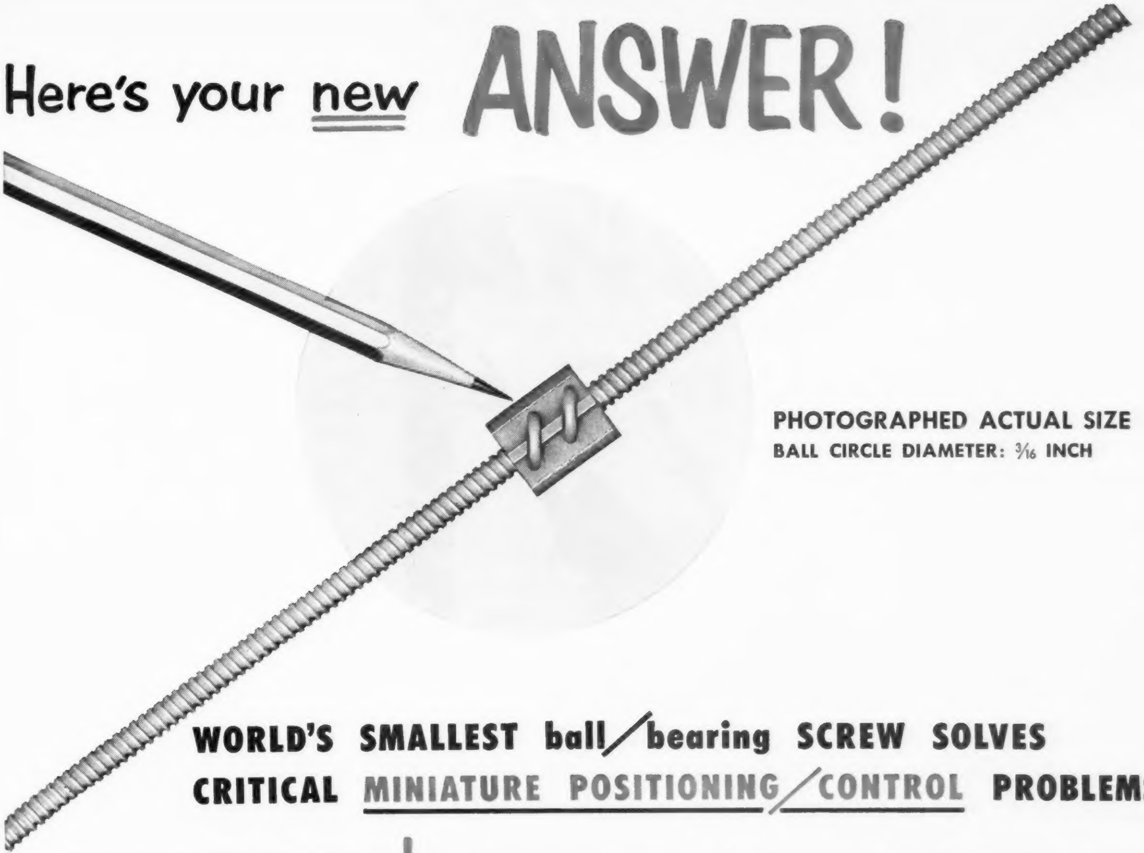
Gas Dynamics Symposium To Be Held in Nice

A symposium on Rarefied Gas Dynamics and Aerothermodynamics will be held by the science faculty of the University of Paris July 2–5 at the Centre Universitaire Méditerranéen in Nice. Information may be obtained from Dr. F. M. Devienne, Laboratoire Méditerranéen de Recherches Thermodynamiques, 2 Avenue Villebois Mareuil, Nice, France.

Japan Astronautical Society Begins "Sale" of Mars Land

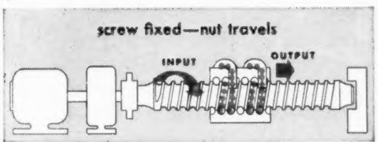
TOKYO, JAPAN—The Japan Astronautical Society has begun "selling" land on Mars in an effort to raise funds and create interest among the Japanese in space flight. The land is being offered in 100,000-tsubo (80-acre) lots, with applicants charged a fee of 1000 yen ($2.78) for submitting applications. The fee is for expenses in connection with the project, with the land to be given to applicants free of charge.

Here's your new ANSWER!

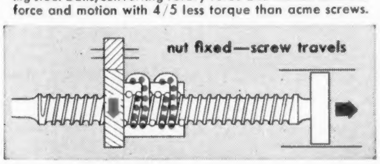


PHOTOGRAPHED ACTUAL SIZE
BALL CIRCLE DIAMETER: $\frac{3}{16}$ INCH

WORLD'S SMALLEST ball/bearing SCREW SOLVES CRITICAL MINIATURE POSITIONING/CONTROL PROBLEMS



NUT TRAVELS: When rotary motion is applied to the screw, the b/b nut glides along the axis of the screw on rolling steel balls, converting rotary force and motion to linear force and motion with 4/5 less torque than acme screws.



SCREW TRAVELS: When rotary motion is applied to the b/b nut, the screw glides along its longitudinal axis on rolling steel balls, converting rotary force and motion to linear force and motion with unprecedented efficiency.

An unprecedented achievement in minimum size and weight—maximum efficiency, dependability and service life for ultra-precise controls.

It's another first from Saginaw—and the possibilities it opens up for improved electrical and electronic controls are limited only by your imagination! Radar tuners, missile and rocket guidance and telemetering systems, automatic switchgear, electronic machinery controls are just a few of the applications where this new miniature Saginaw b/b Screw will solve critical positioning/control problems. *It's so compact and light,* you can save substantially on space and weight. *It's so efficient,* (over 90%) you can use much smaller motors and gear boxes. *It's so precise,* you can position components within .0005 inch per inch of travel. *It's so dependable,* you can rely on remarkably long service life even in adverse environments.

You will find our 1958 Engineering Data Book extremely helpful in planning applications, or experienced Saginaw engineers will gladly make specific recommendations without obligation. Just phone, write or mail the handy coupon.

Saginaw ball/bearing Screw

SAGINAW STEERING GEAR DIVISION OF GENERAL MOTORS • SAGINAW, MICHIGAN
WORLD'S LARGEST PRODUCER OF BALL BEARING SCREWS AND SPLINES

SEND TODAY FOR FREE 36-PAGE ENGINEERING DATA BOOK . . .
or see our section in Sweet's Product Design File

Saginaw Steering Gear Division
General Motors Corporation
b/b Screw and Spline Operation
Dept. 8AST, Saginaw, Michigan

Please send new engineering data book on Saginaw b/b Screws and Splines to:

NAME____________________
COMPANY____________ TITLE________
ADDRESS____________________
CITY__________ ZONE___ STATE____

New Equipment and Processes

Borescope: Model TG-2 borescopes equipped with integral viewing heads are used for internal inspection of small diameter cavities, hollow shafts and tubing. Minimum bore diameters range from 0.160 to 0.280 in., lengths from 5 to 30 in. Kollmorgen Optical Corp., 347 King St., Northampton, Mass.

•

Three-Way Valve: Designed for actuators and instrumentation systems, Series BF42C valve weighs 3 oz and operates at 70 psi. Power consumption is 9 watts at 28 v dc. Eckel Valve Co., 1425 First St., San Fernando, Calif.

•

Mach Number Transducer: Model 2042 transducer uses design advantages of a force balance mechanism to provide accuracy, and operates to very high altitudes over a temperature range of from −65 to +185 F. Barton Mfg. Co., 2520 Colorado Ave., Santa Monica, Calif.

•

Bellows Coupling: A zero adjustable bellows coupling, available for off-the-shelf delivery, allows adjustment on shafts of servo motors, resolvers and synchros, and is designed for 360 deg continual rotation. PIC Design Corp., Sub. of Benrus Watch Co., Inc., 477 Atlantic Ave., E. Rockaway, N. Y.

•

Bridge Kit: Resistance-capacity-ratio bridges in kit form are available for science education, technical schools, industrial testing and quality control. Model C-20 has a capacity range of 10 to 2000 mfd, resistance from 0.5 ohm to 200 megohms, and ratio test ranges from 0.05 to 20. Paco Electronics Co., Inc., Div. of Precision Apparatus Co., 70-31 84th St., Glendale 27, L. I., N. Y.

•

Printed Circuit Connector: To insure alignment between printed circuit boards and connectors, a new receptacle is furnished with floating bobbins. When a misaligned board strikes the chamfer at each end and along the inside edge of the receptacle cavity, the receptacle shifts on its bobbins and allows the board to enter the cavity. Available in 10, 15, 22 and 28 single row contacts, as well as in 30 and 44 double row contacts. Viking Industries, Inc., 21343 Roscoe Blvd., Canoga Park 2, Calif.

WORK IN RAYTHEON'S

EXPANDING

Missile Program

As one of the largest and fastest growing companies engaged in missile work, Raytheon offers unusual opportunities for challenging assignments to:

AERONAUTICAL, ELECTRONIC AND MECHANICAL ENGINEERS

Continued expansion of our development programs and advanced missile design projects offers outstanding opportunities at all levels to experienced engineers desiring assignment in these fields:

SYSTEMS
PACKAGING
MICROWAVE
RADAR
APPLICATIONS
CIRCUIT DESIGN
RELIABILITY
SPECIFICATIONS

AERODYNAMICS (Missile)
- Stability and Control
- Performance
- Air loads

WIND TUNNEL TESTING

AERODYNAMIC HEATING

ROCKET ENGINEERING (Solid)

Consider these overall benefits at Raytheon:

- High starting salary.
- Excellent advancement opportunity.
- Modern facilities.
- Suburban New England living, ½ hour from Boston.
- Educational opportunities at M.I.T., Harvard, etc.

For interview at our suburban laboratory in Bedford, Mass., write, wire, or telephone collect to CRestview 4-7100. Ask for J. Clive Enos.

RAYTHEON *MISSILE SYSTEMS DIVISION*

RAYTHEON MANUFACTURING COMPANY, Bedford, Mass.

Data Processing

(CONTINUED FROM PAGE 44)

information, the Identification Officer declares them to be hostile and selects a Weapons Assigner to organize the attack against them. The computer gives the Weapons Assigner complete information on the planes, as well as on available defensive weapons. The Weapons Assigner controls a number of Intercept Director Teams which can in turn be assigned responsibility for individual intercepts. Thus even a mass raid can be broken down into easily manageable parts.

The computer scope gives the Weapons Assigner a graphic picture of the over-all situation. It shows the five bombers, identified by track numbers, as well as the course and speed of each. It also shows selected geographical references, among them airfields or missile launching sites in the area.

Small squares within the scope identify the points at which interceptors or missiles from any of these airfields or launching sites will intercept the hostile planes. Beneath these squares, time to intercept is shown. Vector lines from the airfields or launching sites indicate the initial heading to be taken by interceptors or missiles from these sites.

All this information is normally available to the Weapons Assigner within one minute after hostile objects are first sighted. On the basis of the information, he decides which defensive weapons to use and which airfields or launching sites they will come from. Intercept Directors at these points are informed of his decision and send up the weapon selected.

Computer Takes Over

Thus far the defense has been based to a large extent on logic. At this point, however, it becomes a matter of computation. In the case of an interceptor, it is completely controlled by the computer, once it gets into the air. The computer calculates the trigonometry necessary to direct the plane to the exact point in the sky where it will meet the target and transmits this information to the plane's autopilot. It trains the plane's radar on the target and, in effect, says "go get it." Then it guides the plane back to its base. In the case of a missile, the computer has a similar function.

Once defensive weapons are in the air, they too are assigned track numbers, and their progress can also be observed on the computer scope, which provides either an over-all picture of the air situation or narrows down to take in smaller areas or even individual intercept attempts.

While the SAGE computer could not in its present form be used to intercept intercontinental ballistic missiles, it could be adapted for such purposes. One necessity, of course, would be an effective long-range radar; another, anti-missile missiles capable of intercepting such weapons in the limited amount of time that would be available.

The computer which is the heart of the SAGE system is not only one of the largest, but also one of the most remarkable data-processing machines ever built. Containing over 75,000 vacuum tubes, it requires a separate, and equally large, powerplant all its own to operate. Completely new, and with tremendous speed and capacity, it has made digital computers fashionable for solving military problems.

Despite its size, it is extremely reliable, with outage time held down to six hours per year. This has been accomplished through a unique system in which spare parts switch themselves into the system when something goes wrong. In operation, a deliberate effort is made to blow out all the tubes once a day by placing a heavy load on them. Spares are also checked in this manner.

Equally remarkable is the fact that, while the Lincoln Laboratory did the basic research on the component parts and conception of the SAGE system, as a whole it is actually the fruit of an unusual cooperative effort in which Lincoln, Western Electric Co., IBM, Bell Laboratories, Burroughs Corp. and the Rand Corp. all worked together to solve a single problem.

The combination of high-performance computer, radar stations and weapon systems in the SAGE network represents one of the most impressive steps yet in electronic technology. It serves to demonstrate how electronics can take over when the task of assimilating and processing information, perhaps the most important element in modern air defense, becomes too great for a human being.

AF Officers Receive Bomarc "On-the-Job-Training"

A pilot group of Air Force officers recently completed actual "on-the-job" training at Boeing's Pilotless Aircraft Div. in preparation for operational use of the Bomarc missile. The group will eventually be attached to the Santa Rosa Island Bomarc operations testing base, now nearing completion in Florida, near Eglin AFB.

in print

Countdown For Tomorrow, by Martin Caidin, E. P. Dutton & Co., New York, 288 pp., illustrated. $4.95.

"Countdown for Tomorrow" is a non-technical mixture of practically everything on the subject of rockets and missiles, garnished with post-Sputnik editorializing and dozens of intimately detailed, highly dramatized accounts of missile launchings. These include a Russian one in which the author all but counts the beads of sweat on the test conductor's brow. Since the latter could only have been written by someone having a blockhouse pass at Kasputin Yar, one might wish that the author had supplied some details more vital than the performance of an unnamed Russian's sudoriferous glands.

Lest the above remarks appear overly critical, let me add that Mr. Caidin's book also contains a good many hitherto unpublished details on the more recent history of many of our missile programs. This reviewer also found absorbing the author's account of the contributions of Russian astronautics pioneer Konstantin Tsiolkovski.

The amount of research work done by the author appears to have been considerable. No errors were found in areas that are currently considered unclassified except some cases which might be excused as literary license. The author extends his license perhaps too far in presenting as fact some details which, since they still are under security wraps, can be only surmises. Occasionally, these surmises are quite wide of the mark.

In view of this reviewer's Navy background, he was possibly oversensitive to omission of any mention of many significant Navy rocket developments, such as the first successful turborocket (Aerojet), the Navy-developed engine (Reaction Motors) which powered the Navy D558-2 and the Air Force X-1, X-1A and MX774.

In many of Mr. Caidin's analyses of the causes of our present less-than-satisfactory situation in the ballistic missile and space flight fields, the author exhibits keen insight. This, of course, is only another way of saying that this reviewer agrees with the opinions expressed.

"Countdown for Tomorrow" will be of particular interest to those who have not previously read an account of the highlights of rocket history, to those interested in some of the background of many postwar rocket programs, and to those interested in the mutual finger-painting and Monday-morning quarterbacking that blossomed after the Russians beat us in the first lap on the race to space.

—**Capt. Robert C. Truax**
Air Force Ballistic Missile Div.

BOOK NOTE

"**Interplanetary Travel,**" by A. Sternfeld (59 pages, Imported Publications and Products, 4 W. 16th St., N.Y.C., 50 cents), is an elementary survey of space flight of interest primarily because it represents the current Russian viewpoint on the subject. Originally published in Moscow, the booklet covers space ships, artificial satellites and space journeys, but reveals little in the way of original Soviet thinking on such subjects. On the basis of this publication at least, Soviet astronautical technology would appear to be on about the same level as our own. —**I.H.**

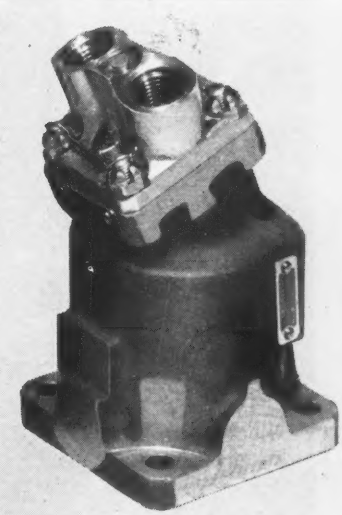
FOR AIRCRAFT AND MISSILE APPLICATIONS:

Variable Pump Design Breakthrough!

...*by* VICKERS

Variable hydraulic output from constant displacement package

NEW MINIATURIZED
VARIABLE DISPLACEMENT
3906 Series ▪ Weight...2.4 lb



STANDARD
CONSTANT DISPLACEMENT
3906 Series ▪ Weight...2.1 lb

- 48% weight reduction—70% smaller envelope*
- 12,000 rpm for aircraft applications
- 18,000 rpm for missile use
- 24,000 rpm for intermittent duty
- 9.7 gpm delivery at 24,000 rpm
- 17 hp (over 7 hp/lb) at 24,000 rpm and 3000 psi
- 98% volumetric efficiency—92% overall efficiency
- Uses proven Vickers 3000 psi rotating pumping element
- Integral automatic pressure compensator
- Extremely rapid response
- Minimum external sealing elements
- Minimum number of moving parts*
- Broad range of control methods available
- First of a new complete line
- Power saving (and heat rejection) advantages of variable displacement at fixed displacement weight and envelope.

*Compared to standard 3000 psi Vickers Series PV-3906 variable displacement axial piston pump.

For further information write for Bulletin No. A-5233.

VICKERS INCORPORATED

DIVISION OF SPERRY RAND CORPORATION

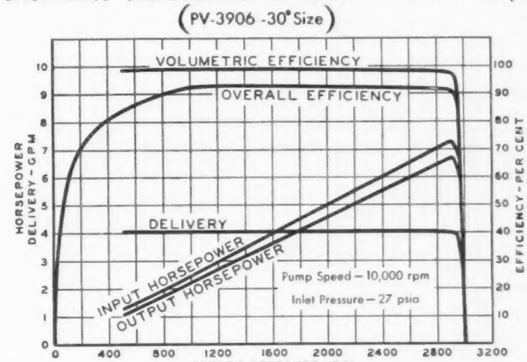
Aero Hydraulics Division

Engineering, Sales and Service Offices:

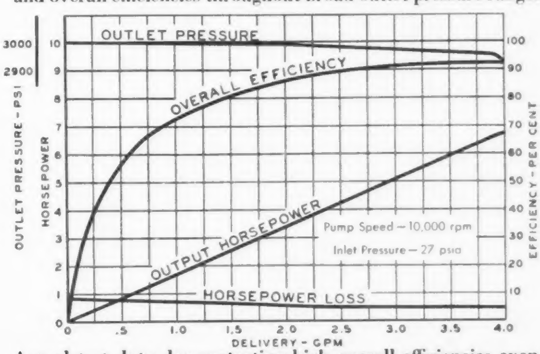
ADMINISTRATIVE and ENGINEERING CENTER
Department 1400 • Detroit 32, Michigan

TORRANCE, CALIFORNIA • 3201 Lomita Boulevard
P.O. Box 2003 • Torrance, California

Performance Characteristics of Model E-0011111 Pump
(PV-3906 -30° Size)



Curves above show actual performance of new Vickers variable delivery pump. Note exceptionally high volumetric and overall efficiencies throughout broad outlet pressure range.



Actual test data demonstrating high overall efficiencies even at partial flows for the new Vickers variable delivery pump. Note low horsepower loss throughout entire delivery range.

ICBM Inertial Guidance

(CONTINUED FROM PAGE 47)

countered in being rocketed into space while performing to accuracies expected of hand-tailored laboratory equipment. To produce such components requires new attainments in precision: Tolerance control to a few atomic diameters, balance to less than a dyne for components having a mass of half a kilo.

Typical of the components that Arma has developed to fulfill these needs is its two-degree-of-freedom gyro. In the past, single-degree-of-freedom gyros have been used universally for inertial navigators. The two-degree-of-freedom gyro fundamentally differs from the single-degree type in that its rotor remains fixed in space, while the platform is slaved to it. In the single-degree-of-freedom gyro, the gyro is forced to turn with the platform and the error is sensed on the free axis by the degree of precession of the gyro. Operationally, the two-degree-of-freedom gyro has two major advantages. One gyro is capable of establishing spatial rigidity about two axes in space, rather than only one. Secondly, it is frequently found that stabilization requirements for the platform servos are very much simplified with two-degree-of-freedom gyros.

Needless to say, the development of such equipment requires highly specialized facilities, such as a controlled atmosphere laboratory, where the gyros are assembled in atmosphere almost completely free of dust, and a space reference laboratory, where highly precise test equipment permits evaluation of gyros in a coordinate system fixed with respect to the stars.

The range of ICBM's is critically dependent upon the total weight that must be accelerated to the terminal velocity. Arma has made great strides in its weight reduction program. The attack on this problem has been two-fold: System simplification and miniaturization. The photo on page 45 shows the results that can be attained through miniaturization. In this case, improvement is achieved partially through the use of three-dimensional packaging, resulting in a reduction of the weight-to-structure ratio from 1:1 to 2:1, and from the use of more advanced components and circuits.

The military utility of the ICBM will hinge upon its *reliable* field operation. All too frequently in the past it has taken years of field operation to bring a weapons system to a reasonable level of reliability. Needless to say, in the case of the ICBM, attaining this reliability will be an impressive task, particularly in the light of the great number of parts involved and the great pressures always present to compromise in favor of operational parameters where the result is more immediately apparent.

A mere 50 per cent reliability for the over-all weapons system means that individual components must possess reliability of the order of only two failures in a million parts. If a higher level of system performance is to be attained, individual part accuracies rise rapidly, as shown in the graph on page 47.

Arma's goals call for reaching a high level of reliability long before the missile reaches operational usage. The key to attaining these goals is centered around a four-step reliability program: Design review, inspection, evaluation and correction.

Design review will serve to assist in the engineering development phase by detecting likely trouble spots and recommending modification.

Inspection will assure that the reliability designed into equipment is achieved by proper fabrication.

Evaluation of the manufactured equipment will be directed toward establishing the capacity of the equipment to operate satisfactorily under the environmental strains anticipated in operation. Many of these conditions, such as vibration, temperature extremes and shock, can be adequately simulated within the laboratory. However, many conditions may only be satisfactorily imposed in the field, such as sustained linear accelerations which are required to adequately exercise the gyros. To simulate these conditions, sled testing and actual missile firings will be utilized. Careful analyses and planning must precede the test to insure a maximum of useful results for a minimum expenditure.

Correction of difficulties encountered in the evaluation stage will be rectified and the reliability improved to the desired level.

When SAC missile bases are equipped with inertially guided ICBM's, another step forward in securing our defensive forces against surprise enemy attack will have been accomplished. The fact that inertially guided missiles are completely self-contained and, once fired, require no external communication, yields two major advantages: First, all missiles can be released simultaneously, because no waiting period is required while the missiles are successively handled by costly ground equipment, and hence none will be destroyed on the ground prior to launching. Second, once the missile is fired, no action by the enemy except actually blasting it from the sky can deter the self-contained inertial system from guiding the missile to its target.

Guiding a missile, or speeding flight and flight environmental data back to control and tracking centers, is too much of a job for conventional communication systems. Supersonic speeds call for lightning fast data communications, coupled with the utmost reliability.

Capitalizing on the ease of converting messages into digital form, Motorola scientists and engineers have developed a number of Data Link Communications Systems suitable for piloted aircraft, as well as missiles.

NERVE CENTER FOR DATA LINK SYSTEMS

With Data Link Systems, messages that have been translated into on-off pulses can be transmitted by any of the common modulation schemes with a suitable carrier. The transmitter can be air-borne, ship-borne, or land-based. Received messages are amplified, decoded, and transformed into a form suitable for display, or stored for some future time, or used for direct control through auto pilots, for example.

One of the Data Link Systems designed at Motorola utilizes an all-transistor converter-coupler, packaged in modular form. The total system consists of eight modules, each approximately 4" x 8" x 1½". The fully transistorized circuitry is of the highly reliable diode-matrix type logical circuitry used in many digital computers. The switch type transistors employed are a product of the Motorola Semi-Conductor Division. Indicative of the stringent testing program to which the transistors are subjected is a 1000-hour life test at 85° C.

For another Data Link program, Motorola has designed a system featuring resolver-type outputs. A single time-shared servo amplifier positions anyone of the five resolvers in accordance with commands from the ground transmitter.

These two Motorola Data Link Systems aimed at solving one of the important communication problems of the missile age are examples of the complex programs conducted by Motorola for varied military needs.

MOTOROLA INC.

MILITARY ELECTRONICS DIVISION

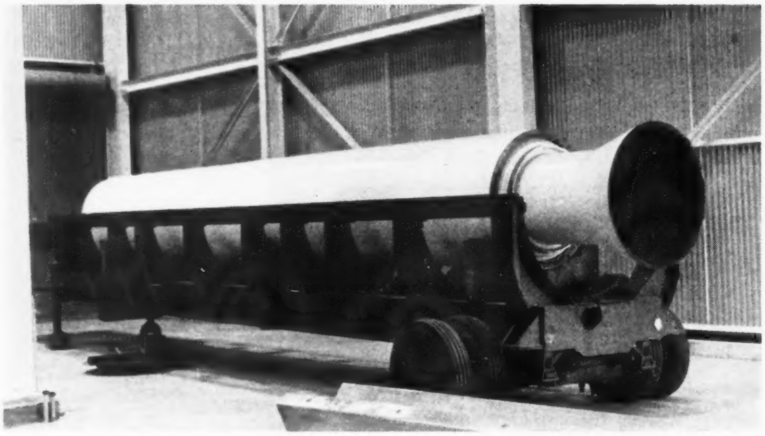
Chicago Area Center • 2710 N. Clybourn Ave. • Chicago, Ill.

Western Area Center • 8201 McDowell Road • Phoenix, Arizona

Positions open to qualified Engineers and Physicists

Communications | Component Design | Navigational Systems | Electronic Countermeasures | Field Engineering | Radar | Equipment Design and Modernization | Missile Systems and Components | Solid State Physics | Beacons

A Big One from Aerojet



This large solid propellant rocket engine, developed and successfully tested by Aerojet, graphically demonstrates the large sizes possible today in SPR engines.

Computers and Simulators

(CONTINUED FROM PAGE 40)

variables has then been determined. Generalized studies such as this have been in operation for some time.

In addition to the missile sizing data which it yields, computation provides information valuable in other areas such as:

1. Trajectory data—velocities, accelerations, range staging times and radar look angles.
2. Exchange ratios—range vs. burnout weight, specific impulse, structural weight, drag, residual propellant, gross weight vs. temperature, skin temperature vs. emissivity.
3. Component weights—Propellant tanks, pressurizing gas bottles, jettisoned parts, wet and dry weights of stages, burnout weight.
4. Internal details—Pressurizing program, tank skin gauges, skin temperatures, bending moments.

Formulas Narrow Study

Furthermore, by careful analysis of results of a great many studies which employ this computational technique, it has been possible to establish simple empirical formulas which yield results agreeing to within a few per cent of the values obtained by the digital computer. These empirical formulas are now employed to narrow the study before the final design is established on the computer.

The choice of analog or digital simulation depends on the nature of the system under study. Digital simulation is strongly indicated when the accuracy required exceeds that obtainable by conventional analog means, such as in the study of long-range missile navigation or in the computation of exact trajectories. Digital simulation is useful in the study of sampled data systems and is almost mandatory for the detailed study of systems actually containing a digital computer.

For most other applications, analog simulation is superior, partly because the analog computer, employing parallel or simultaneous operations, obtains a solution more rapidly than the digital computer employing serial arithmetic operations. The analog computer patch panel can usually be wired and checked faster than a corresponding digital computer program can be written and checked. Minor problem modifications are simple on the analog computer, whereas the program on the digital computer may have to be rewritten and completely rechecked. Also, the graphic output of the analog computer presents the results in a form which is easy for most engineers and scientists to understand and utilize.

Of perhaps greatest importance is the fact that a one-to-one correspondence actually exists between elements of the system under study and elements of an analog computer. This correspondence allows the engineer or scientist to obtain a "feel" for the system and enables him to explore design alternatives by direct manipulation of the corresponding elements in the analog computer circuit.

Two areas of missile development in which considerable simulation has taken place at the Space Technology Laboratories are those of ballistic missile guidance and control. The distinction between these functions is made clear by reference to the functional diagram on page 40. The guidance function consists of determining, from measurements of missile position, velocity or acceleration, a set of steering signals which will place the missile, at termination of powered flight, on a ballistic trajectory intersecting the target. The guidance system must also supply a signal to the propulsion system to terminate thrust.

The control system is a system within the missile which accepts steering commands from the guidance system, or possibly from some preset programmer, and actuates control surfaces or gimballed rocket engines to cause the missile to comply with input commands.

The guidance system itself may be divided into two functions. Navigation is the process of determining from the input data a set of error signals, usually in terms of distance or velocity, which relate the missile's performance to some criterion. Steering is the process of converting these error signals into turning commands intelligible to the missile control system. The navigation system must be extremely accurate—about one order of magnitude better than the measurement devices which provide the input data. Hence, guidance simulation, which includes the navigation function, is almost exclusively a digital computer task.

Flexible Program Developed

A very flexible digital simulation program has been developed at our laboratories for use in guidance studies or other trajectory computations. Simulation is divided into two principal parts. One part consists of integration of the dynamical equations appropriate to each stage of flight, and corresponds to the kinematics block of the diagram. The other consists of simulating the guidance system, both navigation and steering, according to the appropriate set of guidance equations.

In calculating unguided trajectories, the guidance is replaced with a precomputed pitch program. This part of the computation may include an iteration which varies firing azimuth and thrust termination points until the missile impacts within a specified distance of the target.

For different guidance studies, the guidance and staging control part of computation may vary from a simplified version of guidance equations to detailed computation which produces commands agreeing to the least significant binary digit, with the commands

computed by the actual guidance computer in the system. To investigate different philosophies of guidance, it is only necessary to supply the appropriate guidance computation. The same kinematics computation may be employed for all guidance studies. The basic trajectory calculations are made in an inertial Cartesian frame assuming an oblate rotating earth with a standard atmosphere. Position and velocity coordinates and other quantities of interest are transformed to other coordinate systems as necessary.

Other variables of interest, such as radar look angles, pitch, roll and yaw angles, attitude, etc., are derived from the basic quantities of missile position and orientation. Missile orientation is specified by a set of unit vectors along the pitch, roll and yaw axes of the missile. These vectors are obtained by solving a set of vector differential equations, using as inputs the pitch, roll and yaw turning rates derived from the guidance part of the computation. Provisions are made for including winds or gravitational anomalies. The simulation includes the effects of a rather simplified control system.

The program is written to handle various configurations as to number of stages, vernier period, etc. At staging, thrust, mass and aerodynamic coefficients are changed appropriately. Staging occurs either under the control of the guidance computation, or, for unguided flights, by means of a programmed velocity, weight or time. The program even checks to see that the missile has not unintentionally gone into a satellite orbit, and, if it has, the computation is terminated without attempting to calculate an impact point.

Subroutine Approach Used

The entire program employs a carefully selected set of building blocks or subroutines to perform necessary computations. The subroutine approach facilitates computational changes to meet the needs of special study programs. In this way, computational changes are possible with minimum rewriting of the computer program.

The steering system is a filter which accepts error signals plus unavoidable noise from the navigation system, and provides suitable steering signals, such as attitude or attitude rate, to the control system. Simulation has proved invaluable in the design of optimum, time-varying, non-linear steering systems which provide maximum guidance accuracy consistent with certain constraints on the amount of maneuvering allowable. Since the steering system operates on error signals, accuracy requirements are not too stringent. Hence analog simulation of steering by itself is possible and often desirable. Statistical techniques are frequently required due to the presence of noise in the input signals.

The analysis and design of missile control systems is a particularly lucrative area for analog simulation and digital computation. The control system must stabilize the missile at all times in the presence of equipment errors, aerodynamic disturbances, propellant sloshing and body bending. It must have a fast response, yet not be unstable at high frequencies. The over-all system, including missile dynamics, is time-varying due to the variation of missile parameters with time, and is non-linear due to the characteristics of some of the hardware used.

Design Must Be Compromise

In general, control system design must be a compromise between conflicting requirements of low- and high-frequency stability. For example, a high gain is desirable from the point of view of tight control to prevent the missile from responding excessively to wind gusts and other disturbances. However, too high a gain reduces stability at high frequencies, where bending and other resonant effects may cause trouble.

A double-pronged simulation attack on this problem enables a satisfactory design to be achieved. One prong consists of a time-varying trajectory study, in which a relatively simple analog model of the missile and control system is "flown" through winds and subjected to other disturbances to determine minimum acceptable gain levels. Complex detail is omitted from this study, since only low-frequency behavior need be examined.

The other prong is shown schematically in the second accompanying block diagram. A detailed analog simulation of the missile and control system is performed at one particular time of flight, in effect "freezing" the system parameters at that time. The system is examined for over-all stability and transient response, and control system design, including gain levels and compensation network parameters, is modified until good results are achieved. The process is repeated at many different times of flight until a final design is obtained.

Digital computation is used extensively in this process to compute bending modes and frequencies from basic structural data, to compute sloshing modes and frequencies from missile geometry data, and finally to

compile these and other data into a form usable by the analog computer.

For those control systems which do not contain significant nonlinearities, an alternate approach to the detailed simulation just described consists of straight digital computation of system frequency response at each time of flight. This is done by determination of the roots of the rather large characteristic matrix representing the linear system equations of motion. It is still necessary to compute bending and sloshing modes first, just as in the previous method. For linear systems, the all-digital approach seems to offer a slight advantage.

Significant Coupling May Occur

The preceding descriptions of guidance and control system simulation assume implicitly that guidance and control may be uncoupled for purposes of analysis. Thus, in the digital simulation of the guidance system, the control system was represented only in a very simplified manner. In analog simulation of the control system, guidance was completely omitted. While these assumptions are usually valid for long-range ballistic missile systems, there are certain cases, particularly those involving guidance with inertial instruments, where a significant coupling between guidance and control may occur.

For such situations, a combined analog-digital simulation method has been developed, largely at the Space Technology Laboratories and at Convair-Astronautics. In this method, guidance and kinematics are simulated digitally, while the control system and missile dynamics are simulated on the analog computer, the two computers operating together in real time in a closed loop. The advantages of each computer are preserved and detailed simulation of the entire system is provided. A requirement for operation of such simulation is the availability of a multichannel analog-digital conversion device to translate data between the computers. Only a beginning has been made in the field of combined simulation; much remains to be done.

Analog simulation has proved of value at our laboratories in several other areas of missile research and development. Among them are studies of attitude control systems for reentry vehicles, involving complex interaction between servo control and aerodynamics; also in detailed simulation of the dynamics of staging of a missile, and in simulation of high frequency vibration effects within a missile.

Digital computation has also proved invaluable in many other areas of missile research and development, such as study of radio propagation in the ionosphere, study of heat transfer through hypersonic boundary layers, and in preparation of missile firing tables.

Missilemen are making more and more use of computers as missile systems and space vehicles become more complex. Graphic evidence of this fact are the large computer establishments arising in industry and universities working in this challenging field.

Continued advances in the state of the computing art will help make possible future breakthroughs in astronautics.

IGY Satellite Panel Proposes National Space Flight Program

The Earth Satellite Panel of the U.S. National IGY Committee has submitted to the administration a 31-page program entitled "Basic Objectives of a Continuing Program of Scientific Research in Outer Space," urging expanded space exploration after the International Geophysical Year ends.

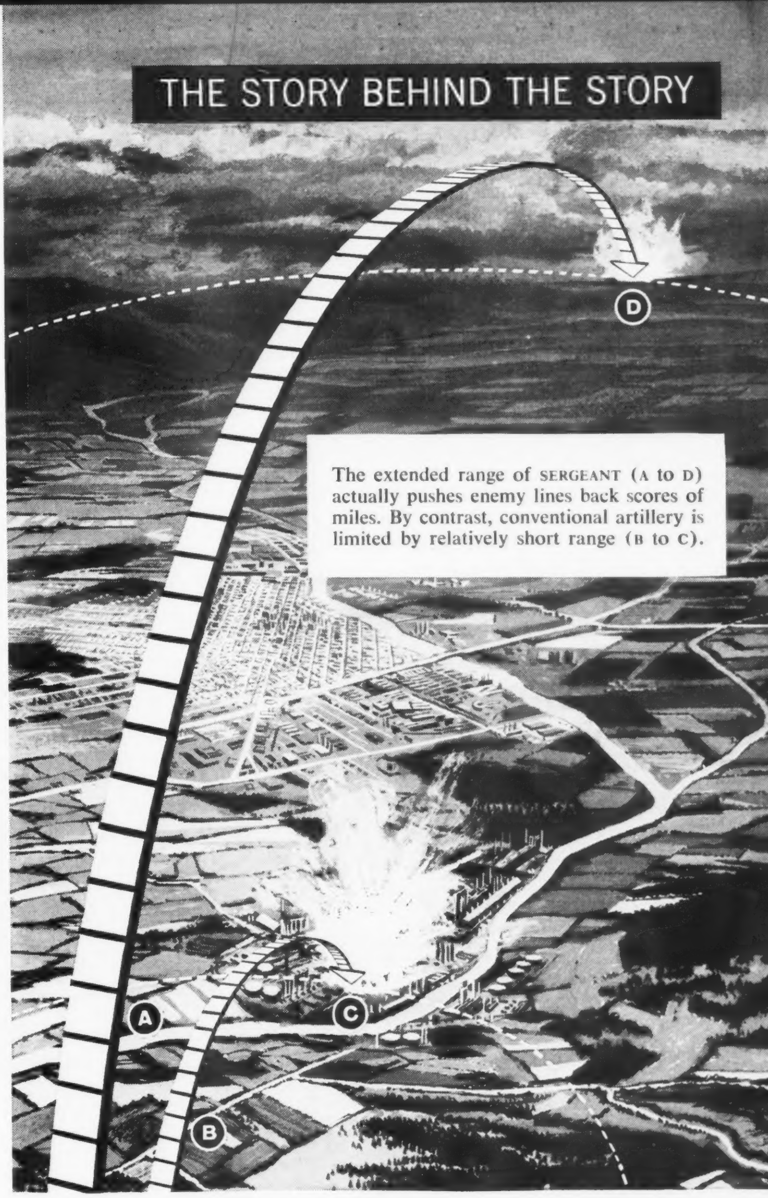
No cost was listed for the program, but one panel member said the consensus of opinion was that a five-year program of this type would cost about $150 million annually.

The panel recommended research projects centering on biological experiments crucial to the eventual attainment of manned space flight; investigations of lunar gravity or mass, magnetic field and atmosphere; planetary and interplanetary probes; determination of the astronomical unit (A.U.) now estimated to be 92,900,000 miles; determination of planetary masses and their effects on the path of nearby space vehicles; and observation of an instrumented re-entry body as it plunged into the planet's atmosphere.

AIEE Air Transportation Forum To Be Held June 25-27

Top engineers of the U.S. and Canada will discuss the electrical design aspects of air transportation at the American Institute of Electrical Engineers' Air Transportation Conference, to be held June 25–27, at the Hotel Statler, Buffalo, N.Y. Technical papers to be presented will deal with high temperature; reliability; missile power packages and power supply parameters; electrical ground support; instrumentation; and radiation effects.

In recent successful test shot, SERGEANT roars into sky. A ballistic guided missile, SERGEANT is guided for precision flight to target. New guidance system cannot be detected in operation.



NEW SERGEANT MISSILE WILL GIVE U.S. ARMY GREATER STRIKING POWER

Development of the new SERGEANT ballistic guided missile is a timely reminder that our nation's security requires accurate, highly mobile tactical weapons for ground defense as well as the more spectacular intercontinental missiles so much in the news. In limited or global war, our frontline troops need the support of such a weapon to crush an aggressor's attack long before he comes within the limited range of present artillery.

The SERGEANT missile is the answer... a ready-to-go solid propellant weapon with the ability to carry a nuclear warhead, a truly important contribution to the security and retaliatory power of our ground forces. In defense, the powerful SERGEANT will furnish U. S. Army commanders with mobile firepower that will be ready in minutes to strike at any attacking force. On offense, this highly accurate weapon can join tactical air units in destroying enemy fortifications.

The SERGEANT is being developed by the Jet Propulsion Laboratory of the California Institute of Technology for the Army. In preparation for production, Sperry has been working with JPL since the beginning stages of design and development. Complete production of the weapon system will be carried out by Sperry's Surface Armament Division.

Sperry's many contributions to the U.S. missile program, ranging from complete missiles to major sub-systems such as radars, automatic inertial guidance systems, electronic countermeasures, and automatic missile checkout systems, account for its selection as system manager for the production of SERGEANT.

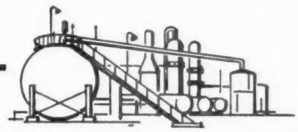
SPERRY SURFACE ARMAMENT DIVISION
GYROSCOPE COMPANY
Great Neck, New York
DIVISION OF SPERRY RAND CORPORATION

Index To Advertisers

Correction: Rez-Coat is not a division of H. I. Thompson Fiber Glass Co. as listed in March issue.

NOW

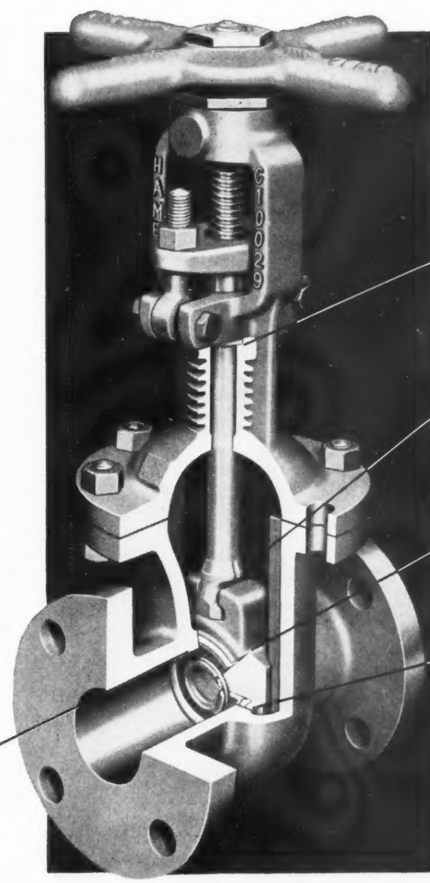
Hamer
Vented-Chest GATE VALVES

for Liquid Oxygen—


Hydrogen Peroxide Service


Safe, Vapor-Tight Shut-off of Hard to Handle Liquid Propellants . . .

Proven under actual environmental field conditions, these new Hamer "Vented-Chest" Gate Valves are contour engineered to provide smooth surfaces and clean lines without objectionable cavities where contaminating particles are often encountered. Seal in one side of wedge only vents chest of valve to pipeline eliminating possibility of pressure build up within the valve. Valves seal equally well with line flow in either direction. Air operated models available.



Chevron Packing

Chevron Packing is long lasting, sure-sealing, expands as pressure increases to prevent escapage.

Chest Vented to Pipe Line

Seal on one side of the wedge vents chest to pipeline, thus possible locked-in pressure build-up in valve interior is prevented.

Micro-Finish Wedge

Seating surfaces of the wedge are precision finished to provide an exacting metal-to-metal fit.

Positive Shutoff Seal

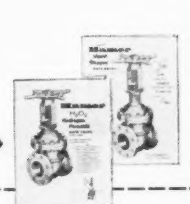
Located in one side of the wedge, this seal compresses against valve seat forming an absolute **shut off.**

Integral Body Seat

Integral seat in the body eliminates threads, welds, cavities as well as other objectionable surfaces.

Send for these FREE Bulletins

MAIL COUPON NOW



HAMER Valves, Inc.
Box 1851, Long Beach 1, California

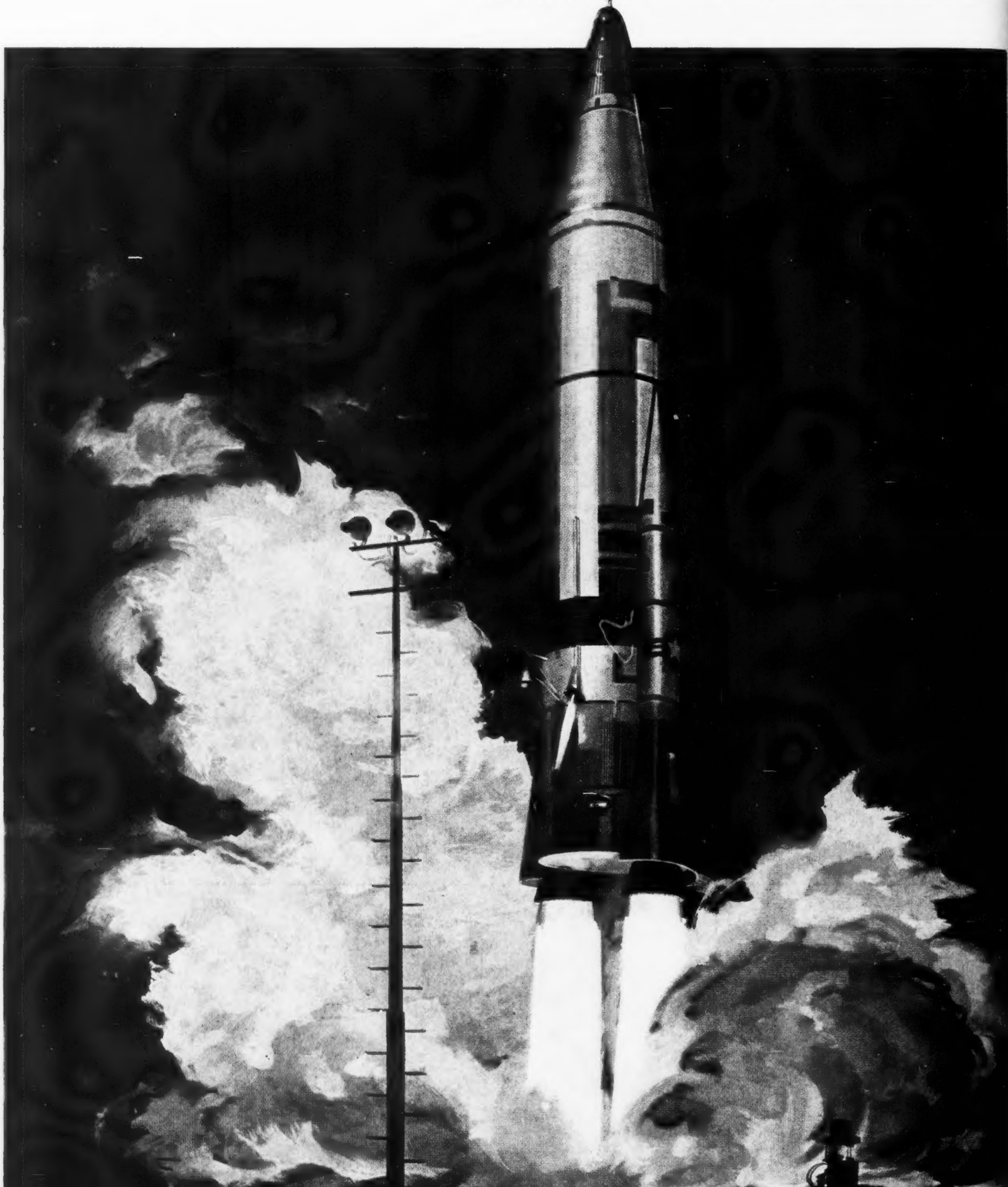
Send me Bulletin on Gate Valves for Lox service ☐
Hydrogen Peroxide service ☐

NAME________ TITLE________
COMPANY________
ADDRESS________
CITY________ ZONE________ STATE________

Hamer VALVES INC.

Box 1851 — 2919 Gardenia Avenue — Long Beach 1, California

58-1



M

has
d's

ATION

7 19